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Comparison of Lean Construction in India and United States of America

Vedangi Mahashabde
Western Kentucky University, vedangi.mahashabde361@topper.wku.edu

COMPARISON OF LEAN CONSTRUCTION IN INDIA AND UNITED STATES OF AMERICA

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COMPARISON OF LEAN CONSTRUCTION IN
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Dr. Daniel Jackson, Director of Thesis

Prof. Shahnaz Ali

Dr. Don Schafer

Dean, Graduate School

8/19/16
Date

I dedicate this thesis to my country; India, my parents and my husband, who are a great inspiration to me. I dedicate this work to all my friends, family and well-wishers.

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Directed by: Dr. Daniel Jackson, Prof. Shahnaz Aly and Dr. Don Schafer

Department of Architectural and Manufacturing Sciences Western Kentucky University

The concept of Lean Construction has been introduced successfully into the Construction Industry to increase efficiency and profit by elimination of non-value adding activities or 'Waste'. Lean Construction is an adaptation of Lean manufacturing principles and is the future of the Construction Industry in developing as well as developed countries. There has been much study and documentation conducted on 'Lean Construction' in USA. Even though people have started practicing Lean in India, there is lack of documented information available about it. Professionals within the Industry could already be minimizing 'Waste' and/or following Lean principles without the knowledge of the term 'Lean Construction'. This thesis has reviewed and compared Lean Construction practices and awareness in India and USA.

A questionnaire based study was used to examine practices and collect data about Construction for analysis. Descriptive statistics was primarily used to make inferences from the data. The Lean Construction characteristics of the construction professionals from both the countries were discussed and analyzed. It was inferred that the Construction Industry in both the countries could benefit further from the Lean practices and increase profitability by up to 25%. In general, personnel in the Construction Industry from both the countries need to receive regular knowledge and updates about Lean principles in order to optimize resources effectively.

Keywords: Indian Construction Industry, Lean Construction, Lean Thinking.

CHAPTER ONE: INTRODUCTION

The Construction Industry is the largest single industry, consuming tremendous amounts of materials from other industries (Goldhaber, Jha, & Macedo, 1977). Koskela (1992) introduced the idea of understanding construction as a production process. The application of Lean to construction is based upon treating the construction site as a temporary production line and is referred to as 'Lean Construction' (Smith, 2011). With the continuous decline in profit margins and increased competition in construction projects, construction contractors are continuing to search for ways of eliminating 'Waste' and increasing profit (Salem et al., 2005). The Lean system has been proven successful and beneficial in the manufacturing industry. Recently, the Construction Industry has started adapting it in construction projects. The International Group for Lean Construction (IGLC) has made significant contributions to the formulation of theoretical foundation for Lean Construction by abstracting the core concepts of Lean production and applying them to the management of construction processes.

Statement of the Problem

This study attempted to determine how profit and efficiency of construction projects could be increased using Lean Construction Management principles. This study also explored and evaluated differences between construction in India and USA, both; by analyzing the methods of minimum wastage and by Lean thinking implemented in the construction projects.

Significance of the Study

In the USA, recently professionals have started using 'Lean' thinking which is about minimizing 'Waste' in overall production process. This thinking was initiated after

realizing what the future would be with no resources available. Studies show that the wastage of resources in USA is higher as available resources are large compared to the population. This Lean movement could be beneficial worldwide.

India has a very old cultural and historic background. Indians have found several refined methods for the optimum use of available resources by its frequent usage and analysis. Being a highly populated country, available resources do not match the demand of the population. Hence, Indians have adapted methods to avoid 'Waste' and reuse defective items by repairing them instead of discarding.

India is the second fastest growing economy in the world. The Indian Construction Industry is an integral part of the Indian economy. Construction accounts for nearly 65% of the total investment in infrastructure and is expected to be the biggest beneficiary of the surge in infrastructure investment over the next few years. In India, most of the structures are Reinforced Concrete framed structures (Figure 3). The concrete construction process consists of formwork erection, rebar and embedment installation, concrete placement and curing, and formwork removal. During this process, significant amount of raw material is wasted. The Indian Construction Industry generates solid 'Waste' that includes sand, gravel, concrete, stone, bricks, wood, metal, glass, plastic, paper, etc. (Figures 1 and 2) (Siddique, n.d.). The Construction Industry in USA faces similar problems.

The current study contributes to the field of construction in India and USA by analyzing the methods of minimum wastage and implementation of Lean methodology in construction projects within both the countries.

Constituents	Quantity generated (million tons/year)
Soil, sand, and gravel	4.20 to 5.14
Bricks and masonry	3.60 to 4.40
Concrete	2.40 to 3.67
Metals	0.60 to 0.73
Bitumen	0.25 to 0.30
Wood	0.25 to 0.30
Others	0.10 to 0.15

Figure 1. Quantity of materials generated from construction waste in India.

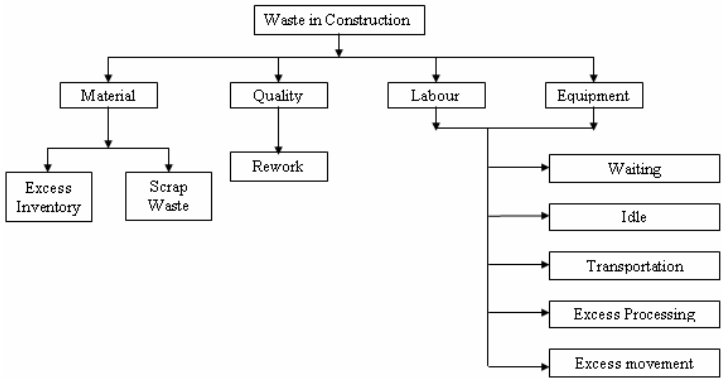

Figure 2. Classification of construction waste in India.

Figure 3. Reinforced Concrete framed construction with reinforcing bars and formwork.

Research Questions

This study sought answers to the following research questions,

1. Is American Construction Industry using Lean Construction principles of minimizing wastage during construction less than the Indian Construction Industry?
2. What is the perception and awareness about Lean Construction among the American and Indian construction professionals?
3. What are the methods of minimizing wastage in India and USA?

Assumptions

It was assumed that the data collected from the sources was unbiased and accurate. Additionally, it was assumed that the Construction Industry functioned on an operating platform different from that of the manufacturing (Koskela, 1992). This platform included four features that differentiate it from that of the manufacturing industry, viz. site production, project uniqueness, complexity, and uncertainty.

Limitations

This study could have been more contributory to the discipline; had it been implemented and analyzed within a live construction project as reported by Salem et al. (2005). However, due to scarcity of small scale construction projects near the location of this study and due to time constraints, a theoretical limitation was conceded in the analysis of construction techniques and methodology. The current study was dependent on secondary resources for the results of Lean implementation at construction projects within the USA. With the survey, there was a limitation of low response rate. Also, there was possibility of some or all the questions not being addressed by the respondents.

Delimitations

In the field of Architecture and Construction, typically it would be beneficial for a project to implement the 'Lean' and 'Six Sigma' principles together for better results. However, this study was delimited to the implementation of 'Lean principles' only.

The database analyzed in this study included contributions by International researchers. The database was specifically catered to the research of Lean Construction. In this way, the study focused on a single segment of Lean research, i.e., Lean Construction and excluded other Lean research segments such as manufacturing.

Lean Construction research includes many areas of research such as Architecture, Engineering, Management and covers a wide spectrum of applied applications as it relates to the Industry. This study did not dissect any specific Lean interest areas, but rather provided an overview of cumulative research contributions by researchers from diverse backgrounds with an interest in Lean Construction study.

Definitions of Technical Terms

1. Lean Manufacturing – A business system for organizing and managing product development, operations, suppliers, and customer relations that requires less human effort, less space, less capital and less time to make the product with fewer defects to precise customer desires (Stenzel, 2007).
2. Reinforced Concrete Construction - Reinforced Concrete is concrete mixture in which reinforcing bars or other types of reinforcement have been integrated to improve one or more properties of the concrete. It is used for the construction of buildings, bridges, and many other types of structures throughout the world. The

basic component materials are cement, sand, aggregate, water, and reinforcing bars which are of steel usually.

3. The Last Planner System (LPS) - A technique that shapes workflow and addresses project variability in construction. The last planner is the person or group accountable for operational planning, i.e. structuring of product design to facilitate improved work flow and production unit control or completion of individual assignments at the operational level. It emphasizes the relationship between scheduling and control over production, and was introduced in 1992. It is the most developed Lean Construction tool (Salem et al., 2005).
4. Six Sigma – Six Sigma is a quality management program that uses statistics to monitor the quality with a goal of producing 3.4 defects or less per million opportunities (Pyzdek & Keller, 2010).

CHAPTER TWO: REVIEW OF LITERATURE

There has been considerable research conducted on the topic of 'Lean Construction'. The purpose of this chapter was to provide a foundation of knowledge about the development of Lean principles and their implementation in Construction Industry with the help of historical research. In order to discover the value placed on the research on Lean Construction, a review of literature on the history of Lean development in construction was essential. The purpose of conducting a review of research on Lean Construction was to further link this study to existing literature about the Lean methods in India and USA.

Overview of Global Construction Industry

The Construction Industry consisted of all companies and consultants primarily engaged in all construction phases of a project such as architects, structural engineers, mechanical, electrical and plumbing consultants, general contractors, and project or construction manager. It also included companies that engage in the preparation of sites for new construction and in subdivision of land for building sites, site surveyors, and quantity estimators and so on. Construction work may include new work, additions, alterations, or maintenance, and repairs (Agyekum, 2012).

Construction Productivity

Time and cost overruns in large-scale construction are very common. Studies suggested that between 70% and 90% of projects exceed the original budget and that the overrun commonly varies between 50% and 100% of the budget. Some well-known examples of significant project overruns include:

- *Sydney Opera House* - Final cost was 15 times more than originally planned

- *Channel Tunnel* - Final cost was 80% more than originally planned
- *Boston Arterial Tunnel* - Final cost was 196% more than originally planned (Construction Industry Institute, 2013).

Causes of Construction Overruns

Causes of construction overruns have been investigated and the most common causes are listed below - excluding issues relating to the commercial supply chain or changes in material or labor rates as these are difficult to control.

- Poor or incomplete design and documentation
- Change in scope by client during construction
- Mistakes during construction
- Delays in decision making or in instructions
- Poor communication and information dissemination
- Poor planning and scheduling
- Weather
- Labor skills and availability
- Disputes
- Incorrect material types or quantity

Various key contributions to improve the workflow are included. Two-way communication and constraints' analysis process is conducted. Efforts of each planner are incorporated and training of the project team is conducted. Traditional practice works on the assumption that pushing more tasks will produce better results (Smith, 2011).

Manufacturing Compared to Construction

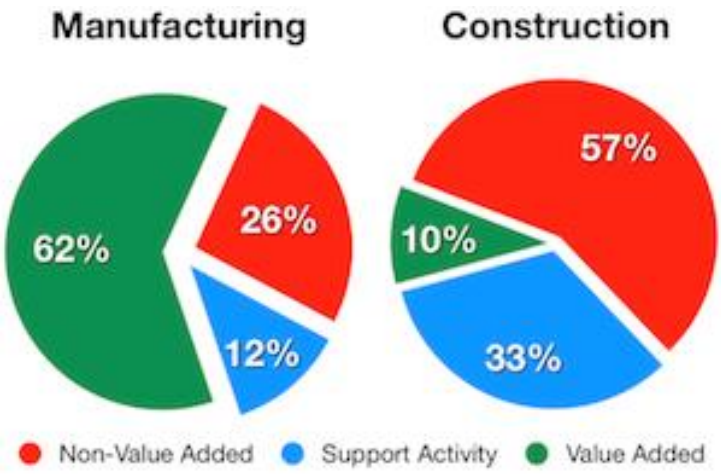

Figure 4. Manufacturing versus Construction

When manufacturing was compared with the construction, the breakdown of time spent on value added and non-value added activities are significantly different. In the construction projects, studies suggested that the construction labor spends around 57% of effort on non-value added activities compared to that of 26% in manufacturing projects (Figure 4). This suggested that the above causal factors such as materials, quality, change, and ineffective coordination are adversely affecting productivity (Smith, 2011).

Types of 'Waste' in the Construction

- *Defects:* It includes incorrect installations, defects in fabrication and errors in punch lists. Not meeting the required code is an additional 'Waste'. Also, rework in construction is rarely measured.
- *Overproduction*: This occurs when the material is fabricated too early or stock material is in the warehouse or at the job site. Printing more blueprints or making more copies of a report than needed is an overproduction.

- *Transportation*: This ‘Waste’ occurs when material has to be moved around the shop or from the lay-down or staging area to the installation point or when it is loaded on the truck or trailer or when hauled to the job site when it is unloaded**.**
- *Waiting*: Construction Industry has an abundance of this ‘Waste’. This includes employees waiting for instructions or materials at the job site, unused time of on-site machinery due to waiting for material to be loaded and hence payment delays.
- *Over processing*: This ‘Waste’ includes over engineering requiring additional signatures on a requisition, multiple handling of timesheets, duplicate entries on forms and getting the estimates multiple times from the suppliers.
- *Motion*: These ‘treasure hunts’ happen when the material is stored away from the job or when the workers look for tools, material, or information. This ‘Waste’ also occurs in the architectural firms or job site trailers when looking for files, reports, reference books, drawings, contracts or vendor catalogues.
- *Inventory*: This includes uncut materials, work-in-process (WIP), and finished fabrications. Some contractors claim that they have no inventory because they job-cost all material. While this may work for accounting, if the material is not yet installed and is still not being used by the customer, it is still a ‘Waste’. This ‘Waste’ includes spare parts, unused tools, consumables, forms and copies, employee stashes, and personal stockpiles.
- *Not Utilizing Human Resources:* Not considering someone’s idea to improve a process or task.

‘Waste’ is found everywhere in construction activities. It has been that way for hundreds of years. This is not a statement of blame, but just a fact. It is so much a way of

life that most construction managers do not even notice it. They accept ‘Waste’ as an inevitable and unpreventable part and add it to the cost of the job. Thus, the customer gets penalized for it. (Construction Industry Institute, 2013)

Overview of Construction Industry in India

Figure 5. Construction Site in India.

India is one of the fastest developing countries in the world. The Construction Industry is the second largest industry in India after agriculture (Bhatla, 2010). It involves the broad spectrum of construction type from real estate to infrastructure such as,

1) Infrastructure – Highways, Airports, Seaports, Railway Stations
2) Commercial – Offices, Shopping Malls, Multiplex Theatres, Hotels
3) Residential – Apartments, Single Family Houses
4) Institutional – Schools, Colleges, Hospitals
5) Industrial – Warehouses, Refineries, Mills, Industrial Plants, Factories

In many countries, construction services may be carried out by general contractors who complete all the work for the proprietor of the project, or by specialized sub contractors who undertake part of the work. Analysis by the World Trade Organization

Secretariat indicated that most countries have a small number of large firms, a moderate number of medium-sized firms and a large number of small firms who specialize in certain fields or who operate in small geographical areas (Agyekum, 2012).

A huge part of the Construction Industry in India is in the hands of civil engineers or contractors. Many people are not even aware of Architecture as a profession. Even if they are aware of it, it is often argued, "Why give more money to architects if contractors or civil engineers can do the same work?" Sometimes, people are misled by contractors or even civil engineers as they call themselves 'architects'. Hence, many construction projects are found with lack of planning and designing with proper vision that results in rework and delays. Another reality is that the Indian Construction Industry still employs the traditional method of project monitoring which includes the earned value estimate of finding schedule and cost variances (Bhatla, 2010). Reluctance in changing the mindset and construction practice is usually found in construction firms in spite of the increased focus on the quality of projects. According to the World Bank Report (2008), globally, Indian ventures are considered non-profitable due to corruption, lack of adherence to contracts and absence of a proper dispute resolution mechanism. Additionally, the Construction Industry in India relies on labor and manpower that is not professionally trained - unlike in the USA (Figure 5).

Overview of Construction Industry in the USA

In USA, the condition is more or less the same as it is in India in terms of client satisfaction. According to Garrison, (2007) the Construction Industry needs to change because if it takes six months to build a house, then 85% of the time is spent on two activities: waiting on the next trade to show up and fixing mistakes. Clemson's Professor

Roger Liska conducted an analysis of productivity on the Construction Industry and found that the average construction worker operates at only 40% efficiency. Critical shortages exist in qualified, skilled workers and labor issue futurist Roger Herman predicts that the situation is only going to get worse. Business Week's 2007 Investment Outlook Report indicates that the return on equity (ROE) for all USA industries is 17.9%, while ROE for the Construction Industry is a mere 9.7%, despite the recent construction boom. Industry customers are frustrated with poor quality, confrontation, excessive change orders in quantity and dollar value, scheduling delays and litigation (Garrison, 2007). Construction automation is a usual practice in the USA. Research shows that the construction professionals in USA have attempted to implement Lean methods into the actual construction projects and have been successful in terms of reducing 'Waste' and making profit.

Lean Manufacturing

After World War II, Japan had to rebuild its devastated infrastructure and manufacturing industry. Toyota introduced the manufacturing process that helped them recover from the war and rebuild its economy. This has come to be known throughout the rest of the world as Lean production, becoming the global standard in manufacturing. As Toyota has continually worked to improve its product, it set an enormous goal - "Give the customers what they want instantly with no 'Waste'. Toyota did not coin the phrase 'Lean thinking'. It was introduced by James P.Womack and Daniel T. Jones in 1996 through a book on Toyota, 'Lean thinking' (Mader, 2005).

Lean thinking is a Total Quality Management (TQM) concept that is based on 'Value'. If the customer is willing to pay for it then it has value. If not, then it is a

'Waste'. Value is the ratio of function to cost. 'Waste' includes defects, over-production, inventory, unnecessary movement of people or goods and waiting around times by employees or product designs that do not meet users' needs (Mader, 2005). The purpose of Lean manufacturing is to improve product cycle time, cost competitiveness and quality by eliminating any 'Waste' in manufacturing process through continuous improvement by a motivated workforce.

Benefits of Implementing Lean

The benefits of implementing Lean can be broken down into three broad categories; Operational improvements, Administrative improvements and Strategic improvements. Even to this day, most organizations that implement Lean do so for operational improvements, primarily because of the perception that Lean only applies to the operations side of the business. However, Lean's administrative and strategic benefits are equally impressive. Some of the benefits of Lean are summarized below.

Operational Improvements

The National Institute of Standards and Technology's (NIST) Manufacturing Extension Partnership recently surveyed forty of their clients who had implemented Lean manufacturing. Typical improvements were reported as follows:

- Lead Time (Cycle Time) reduced by 90%
- Productivity increased by 50%
- Work-In-Process Inventory reduced by 80%
- Quality improved by 80%
- Space Utilization, reduced by 75%

Administrative Improvements

A small sample of specific improvements in administrative functions is (based upon personal experiences):

- Reduction in order of processing errors
- Streamlining of customer service functions so that the customers are no longer placed on hold
- Reduction of paperwork in the office areas
- Reduced staffing demands, allowing the same number of office staff to handle larger numbers of orders
- Documentation and streamlining of processing steps enables the out-sourcing of non-critical functions, allowing the company to focus their efforts on customers' needs
- Reduction of turnover and the resulting attrition costs
- Construction firms could reap the benefits of employing only high performing professionals from the industry

Strategic Improvements

Many companies who implement Lean do not take advantage of the improvements adequately. Highly successful companies will learn how to market these new benefits and turn them into increased market share. One specific example involves a Midwestern USA manufacturer of a common health care product. The industry average lead-time was fifteen days and this company was no different. At the end of the project, this particular company's average lead-time was four days with no products shipped in less than seven days. In order to capitalize upon these improvements, the company began

a marketing advertisement campaign that the customers would receive the product in ten days or the order would be free. The sales volume increased by 20% almost immediately. After making the appropriate improvements to handle the new demand, the company initiated another marketing campaign for only a 10% premium; they would ship within seven days. Again, sales volume increased (by only 5%); and this was because new customers wanted the product within seven days, but more than 30% of existing customers also paid the premium, even though they were already receiving the product within seven days. The end result was that the company increased revenues by almost 40% with no increase in labor or overhead costs. Another key benefit was the company could invoice customers eleven days sooner significantly improving cash flow. (Kilpatrick, 2003).

Lean Construction

Lean Construction was introduced in 1993 in USA by the International Group of Lean Construction (IGLC). The IGLC objective is to meet the customer demands better, dramatically improve the Architectural, Engineering and Construction (AEC) process as well as the product (IGLC, 2010). Lean Construction is a relatively new Construction Management philosophy in developing countries like India. Lean Construction has evolved from Lean manufacturing principles. Lean Construction along with its various tools like the Last Planner System, Just in Time, Total Quality Management and Continuous Improvement has received a lot of attention in developing nations.

Large-scale construction projects suffer from cost and time overruns that are typically a symptom of productivity problems and directly affect overall industry profitability. As a result, methodologies have been developed to reduce the risk of

overruns and improve project outcomes. A number of these methods are based on Lean production principles that focus on identifying value, eliminating ‘Waste’ and creating a smooth flow of materials, information and work (Smith, 2011).

The manufacturing industry is indeed different than the Construction Industry as the construction projects are unique and do not include mass production as in the case of the manufacturing industry. Hence, it is difficult to analyze any construction project from only historical data collected. The laborers working in construction projects are not trained as the professionals and projects are carried out in outdoors where climatic conditions need to be considered. Though that is the case, Lean principles can be modified and implemented in the Construction Industry. The practical value of Lean Construction has been demonstrated in many case studies. For instance, Salem et al. (2005) evaluated the effectiveness of Lean Construction techniques, including the last planner, increased visualization, daily huddle meetings, and first-run studies and their case study showed that these techniques achieved successful outcomes.

When projects are managed with Lean Construction,

- The facility and its delivery process are designed together to better reveal and support customer requirements. Positive iterations within the process are supported and negative iterations are reduced.
- Work is structured throughout the process to maximize value and to reduce ‘Waste’ at the project delivery level.
- Efforts are made to improve total project performance.
- ‘Control’ is redefined from ‘monitoring results’ to ‘making things happen’. Performance of planning and control systems is measured and improved.

- Coordination is improved since the release of work from one specialist in design, supply and assembly to the next is more reliable.

History of Lean Construction

Application of Lean thinking, principles and tools to the lifecycle of capital construction projects is known as 'Lean Construction'. The term 'Lean Construction' is intended to cover the application of Lean thinking, principles and tools to the entire process of a project from the concept through decommissioning. However, the initial reaction to the term within the industry caused opposition and exclusion. Lean Construction was misinterpreted as applying only to the 'construction' phase of a project. Therefore, constituencies like owners and architects did not think that the methodology also applied to them – this is changing. (Sayer & Anderson, 2012).

Main Principles of Lean

Five main Lean principles are:

(1) Value: The customer's viewpoint defines the value

(2) Value Streams: 'Value Stream' is identified through value stream mapping

(3) Flow: Continuous flow of process without interruptions or any non-value added activities

(4) Pull: Use of just-in-time in which the customer 'pulls' the product of service through the processes

(5) Perfection: Continuous improvement through the constant revision of the process (Womack & Jones, 2003).

Other Research

Several authors have studied the application of Lean philosophy to the Construction Industry. Salem et al. (2005) conducted a field study with the help of direct observations, interviews, questionnaires, and documentary analysis to evaluate the effectiveness of some Lean Construction techniques, including the last planner, increased visualization, daily huddle meetings, first run studies, the 5s process and fail safe for quality. The study focused on the first phase of a four-floor university garage project located in the USA. The structure was cast-in-place reinforced concrete. It was found that there is need for behavioral changes and training for effective use of Lean tools. Most of the Lean Construction tools selected for the project are either ready to use, or are recommended with some modifications.

The main obstacle for Lean Construction is that the project manager or the contractor may question the use of the Lean principles at an early stage of implementation of Lean at any new project site. This is due to the fact that the benefits of Lean implementation are seen in long term. The long-term benefit of Lean is that the project is constructed under or at least within the estimated budget and within the scheduled time as Lean emphasizes on ‘minimizing the ‘Waste’.

Song, L. & Liang, D. (2011) performed the contractor’s case study and found that in addition to the rethinking of existing construction processes and practices, there was a need for new tools to implement Lean thinking. Their study observed ‘Waste’ in both project-level contractor coordination and operation-level construction performance. To implement ‘Waste’ elimination solutions at the operation level, construction simulation and 3-D visualization tools were implemented. One of the main reasons leading to

wastage at the construction site was the lack of communication and coordination. Song and Liang developed a vertically integrated scheduling system that features an interface with critical path method (CPM) based schedules, a location-based look-ahead scheduling algorithm, and a graphic weekly planning method to improve it.

Similarly, Dr. Siddique, R. (n.d.) discussed the state of the cement industry, utilization of fly ash and construction 'Waste' in construction related activities in India. The study also discussed potential advances in use of materials such as high volume fly ash (HVFA) which is the byproduct produced during the combustion of coal, ready mix concrete (RMC) and self-compacting concrete (SCC) in construction related activities that may occur in the next decade (2008-2018) in India and their effect on the Concrete Construction Industry. Additionally, it provided information about the developments that have taken place in India related to the utilization of fly ash, cement production and construction 'Waste' as well as potential advances anticipated in the next 10 years for the Concrete Construction Industry through the substantial use of supplementary cementing materials, RMC and SCC.

Bhattacharjee, B. (2010) concluded that there was a need for being concerned about sustainability of concrete in India and minimizing the wastage of precious natural resources by making their efficient and judicious use. This was possible by large-scale mechanization of concrete construction in India through extensive use of RMC practices and prefabrication wherever possible. Furthermore, the study concluded that use of six concrete components namely, coarse aggregate, fine aggregate, water, ordinary Portland cement (OPC) with mineral admixture/blended cement and plasticizer for production of

engineered concrete, instead of non-engineered/semi-engineered concrete could make concrete industry sustainable in India.

CHAPTER THREE: RESEARCH METHODOLOGY

This chapter focuses on the methodological procedures of the present study. It outlines the procedures used to conduct the study and describes different sources of data.

Research Design and Approach

A research design is defined as the blueprint and a detailed plan of how research study is to be conducted (Dao, 2009). The current research was mainly qualitative in its design structure. Qualitative research focuses on attitudes, behaviors and experiences through interviews of groups, institutes and observations (Jacobs, 2010).

Sources of Data

The primary source of the data was the survey questionnaire sent via e-mail. The study also utilized secondary resources such as published peer reviewed journals, books, articles from Lean Construction websites, research papers, and academic thesis and dissertations. For information regarding personal observations, personal interviews were conducted with employees from Kaizen Institute, Pune, India.

The study was conducted in two steps:

1. Gathering data about Lean and the Construction Industry in India and USA, mainly through survey.
2. Analyzing the data to make valid inferences.

Description about Questionnaire

In this study, data was gathered anonymously through a questionnaire survey. For this purpose, more than 150 professionals working in firms related to Construction Industry from India and USA were identified and subsequently requested to complete the

questionnaire. These professionals included architects, structural engineers, project managers, and various consultants associated with the Construction Industry.

The questionnaire was created using the Qualtrics software. The software created a link directing participants to the survey. The invitation to take the survey was distributed via emails. From this, 69 professionals duly filled the survey and were respondents for this study.

The questionnaire included a total of 32 questions. First 3 questions were aimed at clarifying respondents' professional and occupational attributes. Questions 4 to 10 were related to operational characteristics of the firms. The 11th question was critical as it asked if the respondent was familiar with the term 'Lean Construction'. This question was important as respondents from USA might have known the concept and its use while respondents from India might have been implementing the 'Lean principles' without being aware of the technical term 'Lean Construction'. Hence, if answer 'No' was selected the survey skipped to question 17 to 25 asking questions about firm's work practices in detail. If the answer to question 11 was 'Yes' then questions 12 to 16 inquired about Lean practice and benefits to the firm in detail. Questions 26 to 32 were directed towards participant's opinion about initiating and evaluating 'continuous improvement' principles of Lean.

The sample data gathered are displayed and documented in detail in the next chapter. This analysis included displaying summary of descriptive statistics and making inferences from the data. In the conclusion section, important findings from the present research were noted and recommendations were made for further research. Lastly, the

study analyzed if Indian methods of optimization of resources could be applied in the USA and vice versa.

Comparing the Results from India and USA

In order to classify respondents from India and USA, each response was inspected individually. Based on the IP address of computer and with the help of survey, locations of respondent were identified and separated accordingly. Out of all the respondents, 30% were from India, 30% were from USA while 40% of the responses were collected from locations that were unknown.

For these groups, the most occurring response was identified for each question. Also, frequency of all other options selected by the respondents for each question was considered in the explanation of the data. Some important observations were noticed and discussed in the conclusion chapter.

CHAPTER FOUR: FINDINGS/ RESULTS

This chapter discusses the information collected through the survey. Response to each question from the respondents is shown in graphical form and is explained further.

Data from survey

1. Respondent's Education;

#	Answer	Response	%
1	Associate's Degree in	1	2%
2	Bachelor's Degree in	15	32%
3	Master's Degree in	27	56%
4	Doctorate in	3	6%
5	Other, Please Specify	2	4%
	Total	48	100%

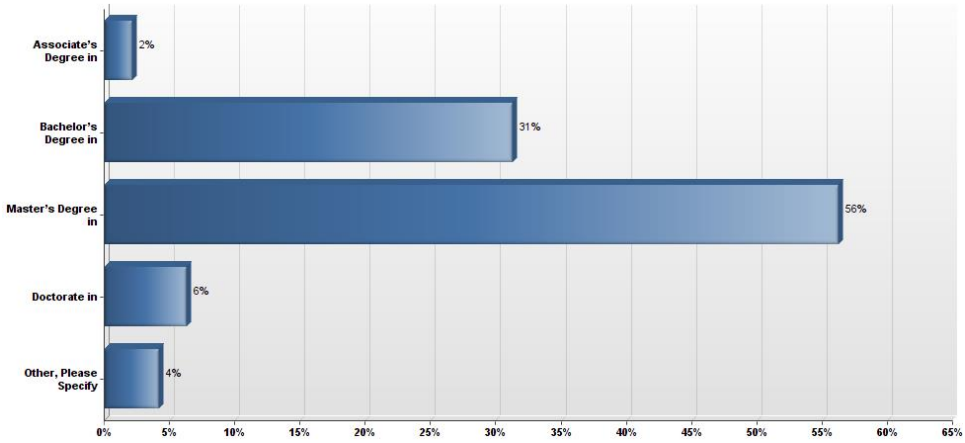

Figure 6. Respondent's education

Data expressed in Figure 6 indicates that majority (56%) of the respondents in this study had formal academic education up to Master's degree. This was followed by 32% respondents with Bachelor's degree, 6% with Doctorate, 4% with high school diploma or other degree, and 2% with Associate's degree. This is shown in Table 1.

Table 1.

Respondent's educational degree in detail

Associate's Degree in	Bachelor's Degree in	Master's Degree in	Doctorate in	Other, Please Specify
	Architecture	Architecture	Law & Architecture	High School
	Industrial Technology	Civil engineering	Business & Technology Management	Diploma
	Architecture	Operations Management	Civil Engineering	
	Civil Engineering	Business Administration		
	Civil Engineering	Quality Management		
	Architecture	Construction Management & Economics		
	English and Philosophy	Industrial Design		
	Architecture	Operations Research		
	Natural Resource Management	Environmental Planning		
	Interior Design	Mechanical Engineering		
	Architecture	Architecture		
	Architecture	Electrical		
	Architecture	Civil Engineering		
		Electrical Engineering		
		Construction Management		
		Electrical Engineering		
		MBA		
		General Architecture		
		Real Estate Finance		
		Historic Preservation		
		Mechanical Engineering		
		Construction Management		
		Electrical Engineering		
		Structural Engineering, Mechanics and Materials		
		Building Engineering and Management		
		Civil Engineering		

2. Respondent's Profession/ Role in the Company;

#	Answer	Response	%
1	Architect	16	35%
2	Consulting Engineer	6	13%
3	Building Contractor	0	0%
4	Construction Project Manager	5	11%
5	Construction Site Leader	1	2%
6	Office Associate	1	2%
7	Other, Please Specify	17	37%
	Total	46	100%

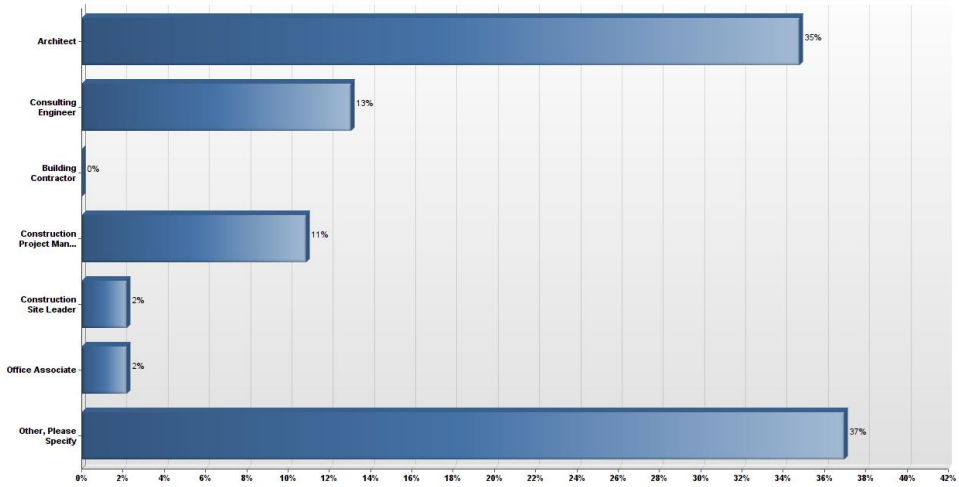

Figure 7. Respondent's profession/ role in the company.

With reference to Figure 7, it was discovered that majority of the respondents in this study had varied roles in their respective company, i.e. 17 individuals (37% respondents), followed by Architects, 16 individuals (35% respondents). Respondents representing Consulting Engineers were the third largest group corresponding to 6 individuals or 13%. There were 5 respondents (11%) who were Construction Project Managers while the remaining 2 individuals (4%) were working as Construction Site

Leader and Office Associate respectively. There was no Building Contractor as a respondent. Table 2 gives an idea about the other roles of the respondents in the firm.

Table 2.

Text reply for respondent's role in the firm

Other, Please Specify
General Engineering Contractor
Senior Research Analyst (Procurement Consultant)
Marketing/Management
QSE manager
Retired as Senior Contracts Manager
Retired as Senior Contracts Manager
Architect-Planner
Risk Management Specialist
Sr. buyer
Systems Analyst
Lean Consultant
Simulation & Modeling Engineer
Real Estate Financial Analyst
Former Engineers Assistant, Current Forestry Tech.
Lean/IPD Coach
Manufacturing Engineer
Student

3. Respondent's Level of Experience (In Years);

#	Answer	Response	%
1	0 – 5	16	34%
2	5 – 10	12	26%
3	10 – 15	3	6%
4	15 – 20	4	8%
5	More than 20	12	26%
	Total	47	100%

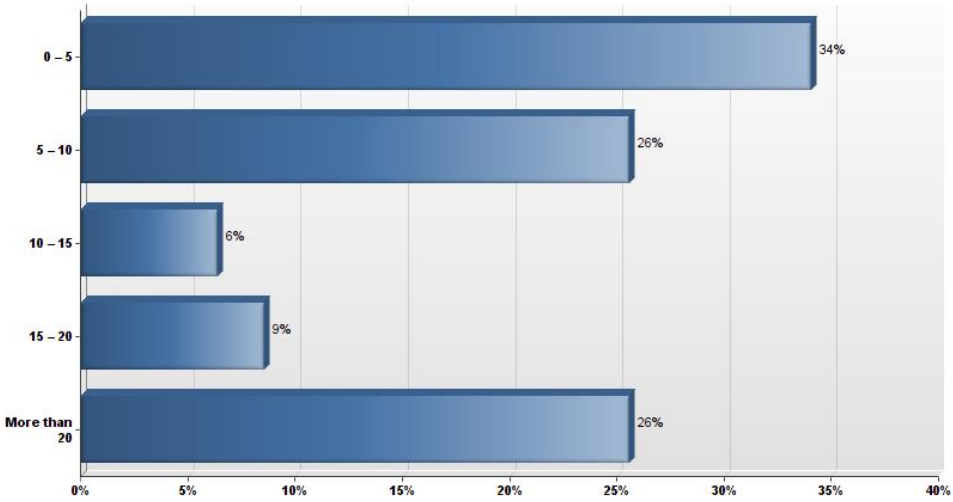

Figure 8. Respondent's level of experience

It can be noticed from Figure 8 that as many as 16 (34%) respondents had work experience of 0 to 5 years. Respondents with experience between 5 to 10 years as well as more than 20 years were the second largest, both corresponding to 12 individuals (26%). 4 respondents (8%) had work experience between 15 to 20 years while remaining 3 respondents (6%) had 10 to 15 years of experience in the Industry.

4. Company's Complete Name
Harbco General Contractors
James Sommerville Inc
Beroe Inc.
Akzo Nobel
Retired from Abu Dhabi Airports Company. Abu Dhabi
Abu Dhabi Airports Company, Abu Dhabi, United Arab Emirates
NBZ architectural consultants
Design Nonstop
Air Liquide USA
Subha Architects
Outerwall
Mogal Raja & Associates
mqa
Shree Architects
Vaastu Sanhita
Global Projects Consulting Group, Inc.
Prowest Constructors
Sanjay Puri Architects, Mumbai
BW Architecture, PLLC
Bhairav Construction
Lynn & Associates

Figure 9. Company's complete name

21 respondents provided the name of their company or firm as indicated in Figure 9.

5. Geographical Operational Locations of the Firm;

#	Answer	Response	%
1	All within India	14	39%
2	All Within USA	12	33%
3	Spread within the Country and Abroad	10	28%
	Total	36	100%

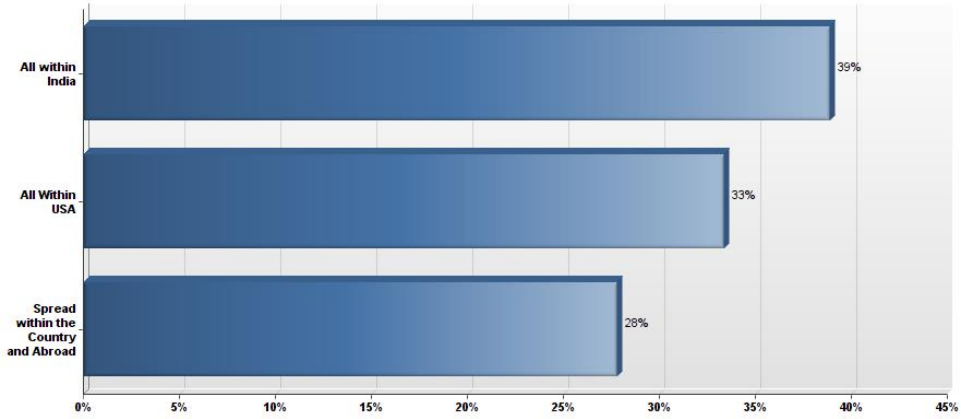

Figure 10. Geographical operational locations of the firm

Data from Figure 10 indicates that 14 individuals (39%) taking the survey were from Indian firms and 12 individuals (33%) were from the USA. There were 10 respondents (28%) associated with firms having multiple branches spread within the country (India or USA) and abroad; in other words, the firms were working globally.

Based on the analysis of location of respondents, 21 and 20 respondents were from India and USA respectively. Locations of remaining 28 respondents were unidentified.

6. Areas of Expertise of the Firm (More than one choice can be picked!);

#	Answer	Response	%
1	Primarily Residential Projects (Bungalows/ Individual Houses, Apartments, etc.)	7	21%
2	Primarily Commercial Projects (Theaters, Institutions, Religious Buildings)	7	21%
3	Both Residential & Commercial Projects	18	55%
4	Industrial Facilities	10	30%
5	Energy Efficient/ Green Buildings	5	15%
6	Infrastructural Facilities (Airports, Highways, Dams, Bridges, Tunnel Construction)	5	15%

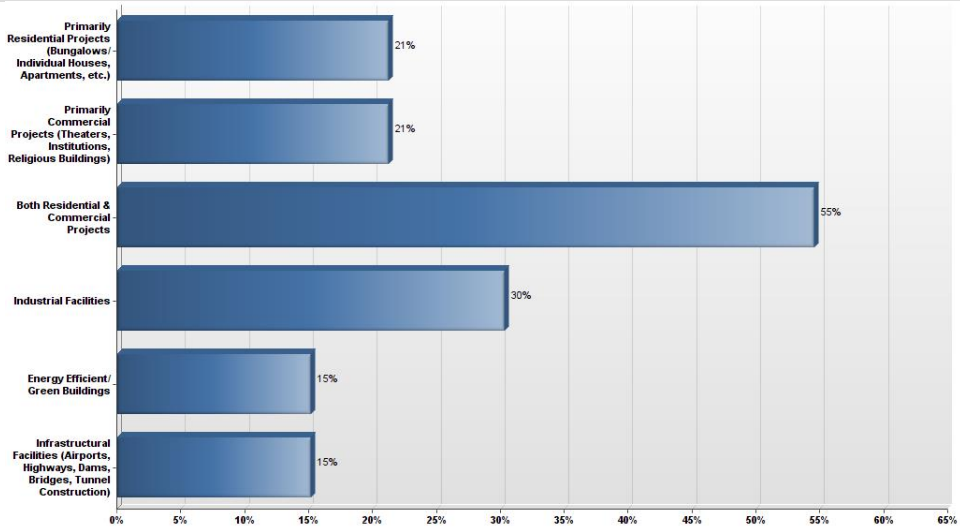

Figure 11. Areas of expertise of the firm

Response to question 6, as shown in Figure 11, indicates that 55% individuals taking the survey were working in the firm with expertise in both residential and commercial projects followed by 30% individuals with expertise in industrial facilities. 21% respondents were from firms with expertise primarily in residential and commercial projects respectively. 15% individuals were from firms with expertise in energy efficient/ green buildings and infrastructural facilities each.

7. The firm is active in Construction Industry since (In Years);

#	Answer	Response	%
1	0 – 5	8	25%
2	5 – 10	2	6%
3	10 – 15	2	6%
4	15 – 20	5	16%
5	More than 20	15	47%
	Total	32	100%

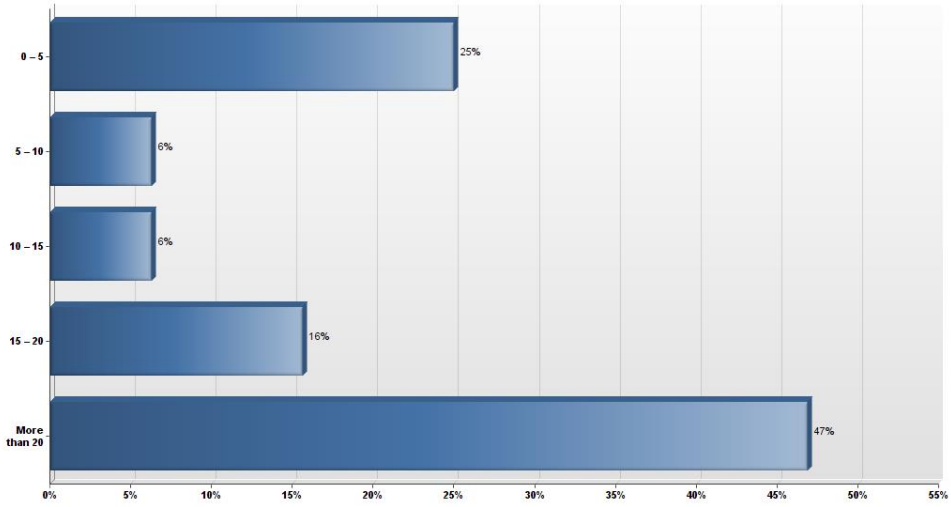

Figure 12. Working years of the firm in Construction Industry

With reference to Figure 12, it was found that the majority of the respondents in this study were working in the firms with more than 20 years of experience in Construction Industry (47%), followed by 25% individuals from the firms with 0 to 5 years of experience. Respondents working in the firms with 15 to 20 years of experience were the third largest group corresponding to 16%. There were 2 respondents (6% each) who were working in the firms having 5 to 10 and 10 to 15 years of experience in Construction Industry each.

8. Average number of employees in the firm (Including Construction Sites and Offices);

#	Answer	Response	%
1	10 – 100	23	70%
2	100 – 500	4	12%
3	500 – 1500	1	3%
4	More than 1500	5	15%
	Total	33	100%

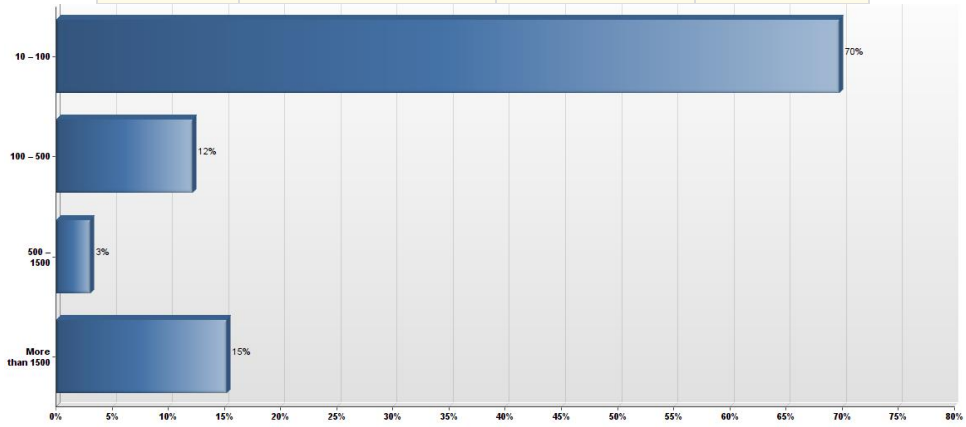

Figure 13. Average no. of employees in the firm

Data from Figure 13 indicates that 70% respondents were working in the firms with an average of 10 to 100 employees. 15% respondents were from large firms with an average of more than 1500 employees. 12% respondents were working in the firms with an average of 100 to 500 employees. Only 3% respondents belonged to the firms having 500 to 1500 employees at an average.

9. Average annual turnover of the firm; (In Million American Dollars)

#	Answer	Response	%
1	$ 1 – 10	11	41%
2	$ 10 – 100	9	33%
3	$ 100 – 1000	2	7%
4	More than $ 1000	5	19%
	Total	27	100%

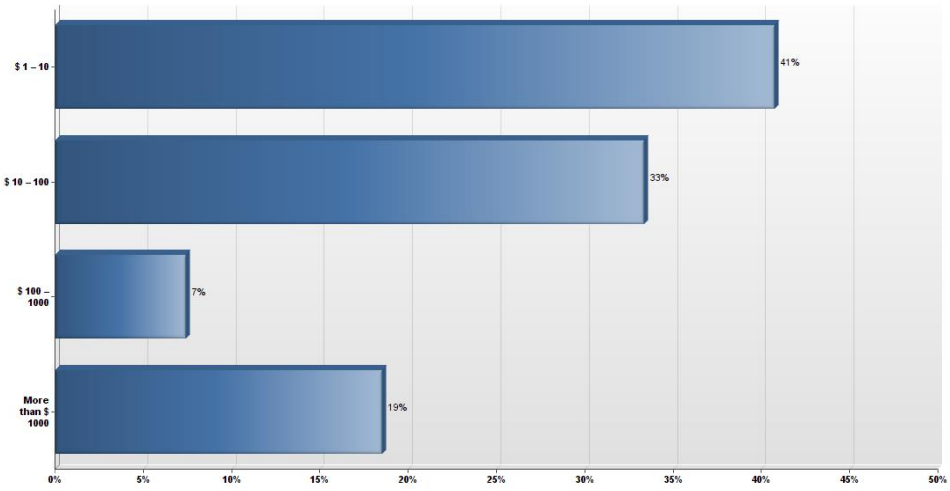

Figure 14 . Average annual turnover of the firm

Figure 14 indicates that majority of the respondents were working in the firms with an average annual turnover of up to $10 million (41%). 33% of respondents were from firms with an average annual turnover of $10 to $100 million. Respondents working in the firms with an average annual turnover of more than $1000 million were the third largest group corresponding to 19%. There were 2 respondents (7%) who were working in the firms having an average turnover of $100 to $1000 million per year. In general, the survey represented professionals from the firms with turnover of less than $100 million.

10. Major Clients of the firm;

#	Answer	Response	%
1	Public / Government Organizations (State/ Federal)	3	9%
2	Private Individuals and Organizations	16	47%
3	Both Public and Private Organizations	15	44%
	Total	34	100%

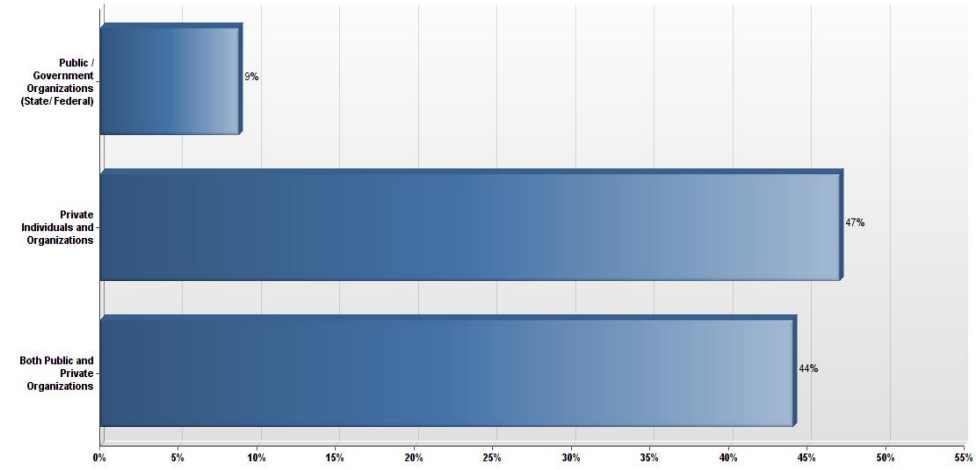

Figure 15. Major clients of the firm

Response to question 10, as shown in Figure 15, indicates that 47% respondents to the survey represented the firms having private individual organizations as their clients. 9% firms were working for public/government organizations while 44% firms had clients in both public and private organizations.

11. Are you familiar with the term 'Lean Construction' as an approach in managing the construction process?

#	Answer	Response	%
1	Yes	16	46%
2	No	19	54%
	Total	35	100%

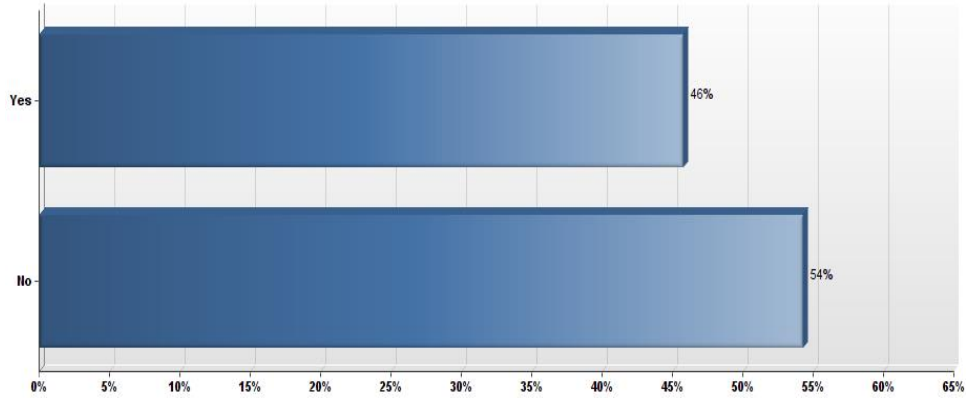

Figure 16. Respondent's awareness about the term 'Lean Construction'

Figure 16 indicates that there was a mixed response to the awareness of the term 'Lean Construction'. 54% respondents from India and USA did not know the term 'Lean Construction' while remaining 46% respondents knew the term.

12. Do you currently utilize Lean Construction methods or concepts in your construction projects?

#	Answer	Response	%
1	Yes	10	71%
2	No	4	29%
	Total	14	100%

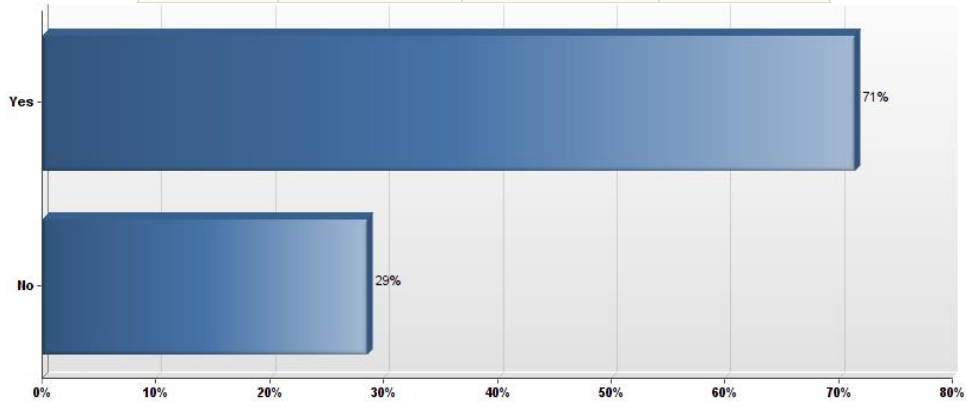

Figure 17. Usage of Lean Construction methods in the projects

Figure 17 indicates that 71% respondents belonged to the firms that utilized Lean Construction methods whereas remaining 29% individuals worked for the firms not utilizing Lean concepts.

13. For how many years has the company been utilizing Lean Construction concepts and methods in the projects?

Text Response	
05	5
20	6
Eight	6
10 +	Two
0	NA

Figure 18. Duration of implementation of Lean Construction methods in firm's projects

Altogether 10 respondents answered question 13 as indicated in Figure 18. There was a firm using Lean concepts for 20 years as well as a firm not using Lean concepts at all.

14. The following choices represent opinions expressed in recent editorials and publications. Which of these definitions of Lean Construction is closest to your own?			
#	Answer	Response	%
1	The holistic pursuit to the elimination of material 'Waste' on a construction project	2	13%
2	Kaizen (Japanese word for continuous and step-wise quality improvement)	2	13%
3	The continuous process of eliminating 'Waste', meeting or exceeding all customer requirements, focusing on the entire value stream, and pursuing perfection in the execution of the constructed project.	10	67%
4	Other	1	7%

Other			
1 page reports, the 5 Whys, 5S, once in a while Kaizens			
	Total	15	100%

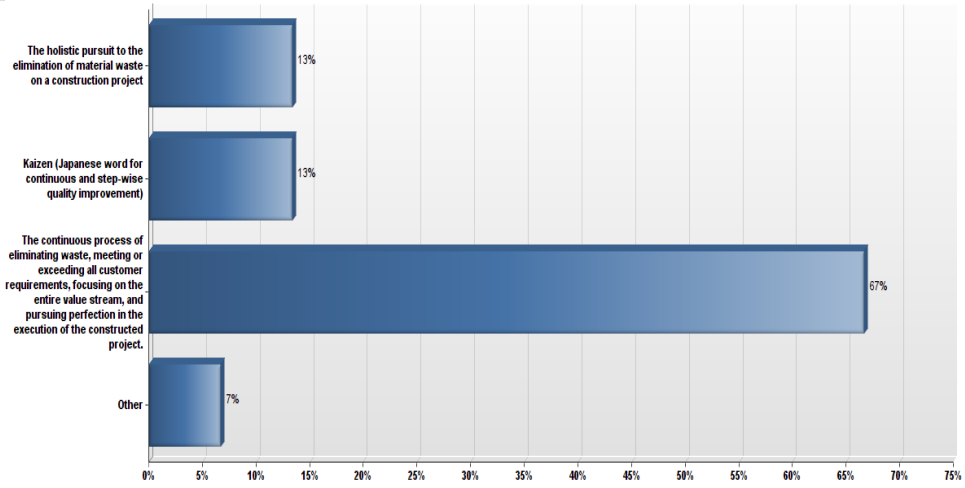

Figure 19. Respondent's opinion about definition of Lean Construction

The data in Figure 19 indicates that 67% or the majority of respondents considered that ‘Lean Construction’ means ‘continuous process of eliminating ‘Waste’, meeting or exceeding all customer requirements, focusing on the entire value stream, and pursuing perfection in the execution of the constructed project.’ Remaining respondents supported other definitions from the options shown in Figure 20.

15. Has your company identified tangible benefits from utilizing the Lean Construction practices that have enhanced your company profits?

#	Answer	Response	%
1	Yes (Example)	9	64%
2	No	5	36%
	Total	14	100%

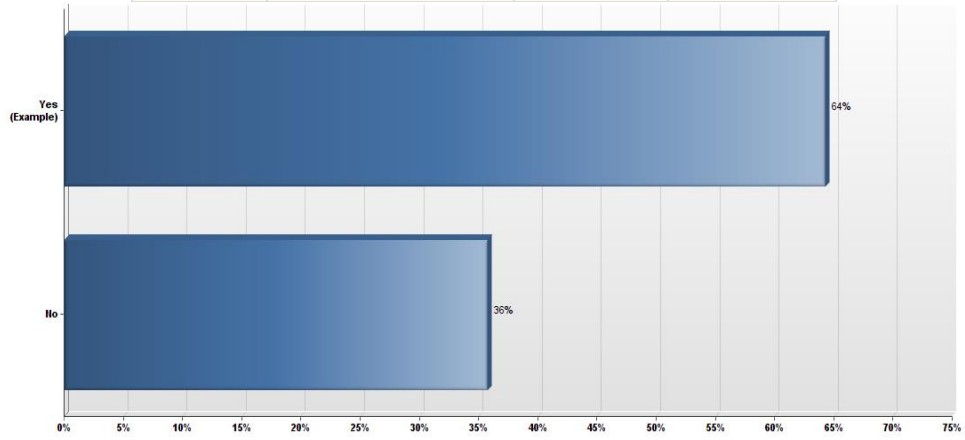

Figure 20. Respondent’s opinion about benefit of using Lean Construction concepts

Figure 20 indicates that 9 individuals (64%) thought that profit gained by the company was due to Lean Construction practices while remaining 5 individuals (36%) thought otherwise. Respondents elaborated the benefits of using Lean Construction concepts and are listed in Table 3. Given the fact that most of the respondents were

academically trained, 36% of them still did not consider Lean as a useful tool was an important observation.

Table 3.

Respondent's opinion about benefit of using Lean Construction concepts

Yes (Example)
Financial saving & no 'Waste'.
Designs are based on site conditions to avoid cut & fill
Being consultants, our role is to work maximum efficiency at planning level on all aspects related to designing as well as construction. Of course day to day involvement is not in our scope of professional services
Improved safety, quality and productivity due to improved processes and better training in those processes
elimination / reduction of landfill cost
I know my company is using some methods, I am not sure about them, so I can't give an example
projects completed on time or before, reduction in the construction costs, fewer injuries

16. What is the profit percentage of your firm due to usage of Lean Construction practices?

#	Answer	Response	%
1	0 – 20 %	8	67%
2	20 – 40 %	3	25%
3	40 – 60 %	0	0%
4	60 – 80 %	1	8%
5	80 – 100 %	0	0%
	Total	12	100%

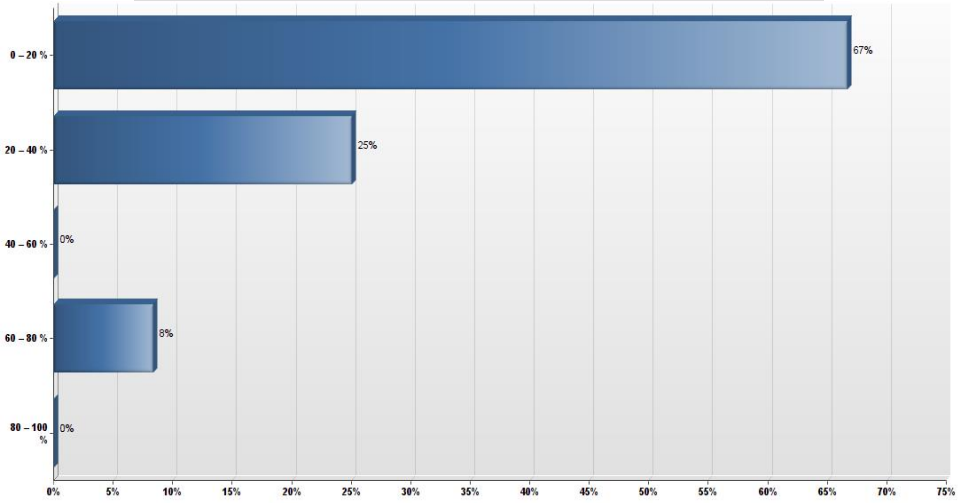

Figure 21. Respondent's opinion about profit % gained due to implementing Lean Construction

Figure 21 indicates that 67% respondents believed that their firm gained 20% profit by using Lean methods in the construction practice. This followed by 25% Respondents who believed that their firm gained 20 to 40% of profit due to use of Lean methods. Only 8% respondents believed that their firm's profit was 60 to 80% due to the

use of Lean practices. No respondent believed that their firm gained either 40 to 60% or 80 to 100% profit by implementation of Lean Construction.

17. Is there a system at the firm that measures and evaluates the quantity of unused and/or unnecessarily purchased materials and tools?

#	Answer	Response	%
1	Yes	6	23%
2	No	20	77%
	Total	26	100%

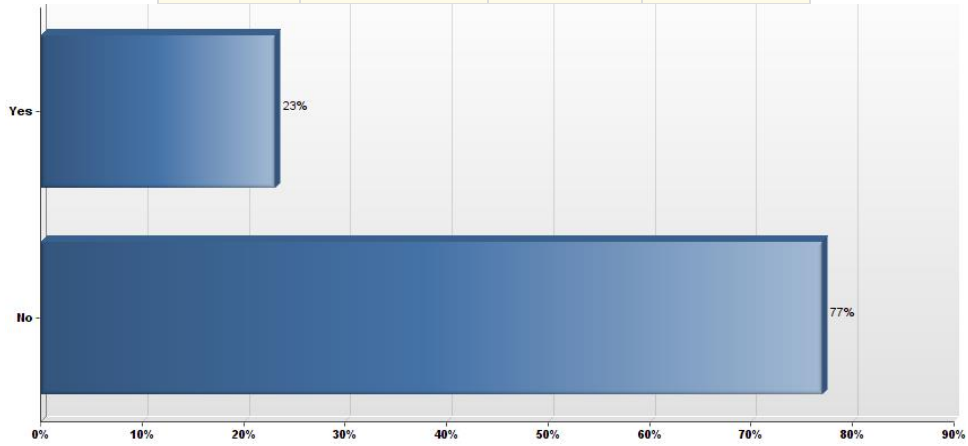

Figure 22. Answer of respondents to Q.17

Figure 22 indicates that 77% of the respondents claimed to have no system to utilize unused material while 23% of the respondents acknowledged the use of such system at their firms.

18. How often do you meet to discuss responsibilities and plans with the professionals involved?

#	Answer	Response	%
1	Each day	2	7%
2	Each week	14	52%
3	Every second week	3	11%
4	As problems arises (when necessary)	7	26%
5	Other	1	4%
	Total	27	100%

Other
Every Month

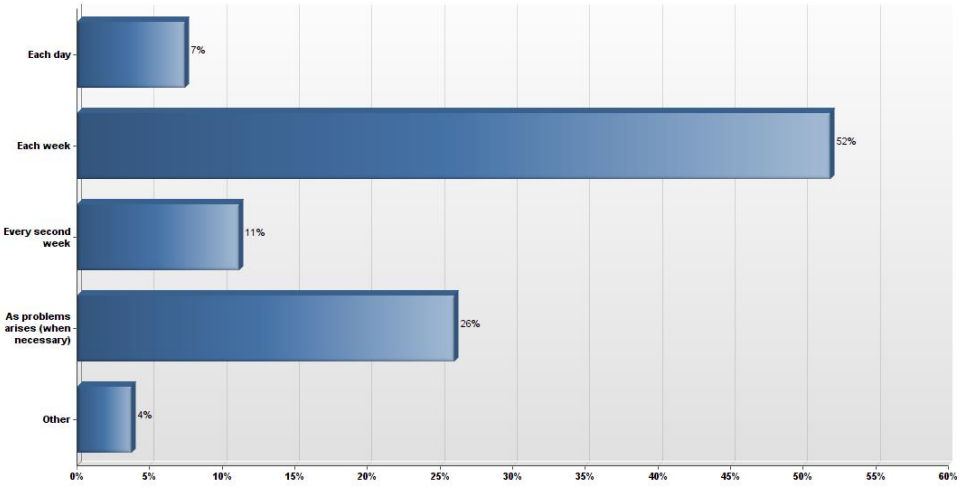

Figure 23. Meeting frequency of professionals for planning discussions.

Figure 23 indicates that almost 70% of the Construction Industry conducted regular communication on a weekly basis. However, there was a significant portion of the industry (26%) that had planned communication as problems arose. There was also one individual (4%) who worked in firm that communicated each month with concerned professionals.

19. Who is present at the meetings? (More than one choice can be picked!)

#	Answer	Response	%
1	Architect	16	64%
2	Consulting Engineer	14	56%
3	Building Contractor	17	68%
4	Construction Project Manager	11	44%
5	Construction Site Leader	13	52%
6	Office Associate	11	44%
7	Skilled workers	4	16%
8	All of the above	4	16%
9	Other, Please Specify	4	16%

Other, Please Specify
Developer/Owner
Superintendent
HSE (Health and Safety Manager)
all of the above varies depending on what stage the project is in

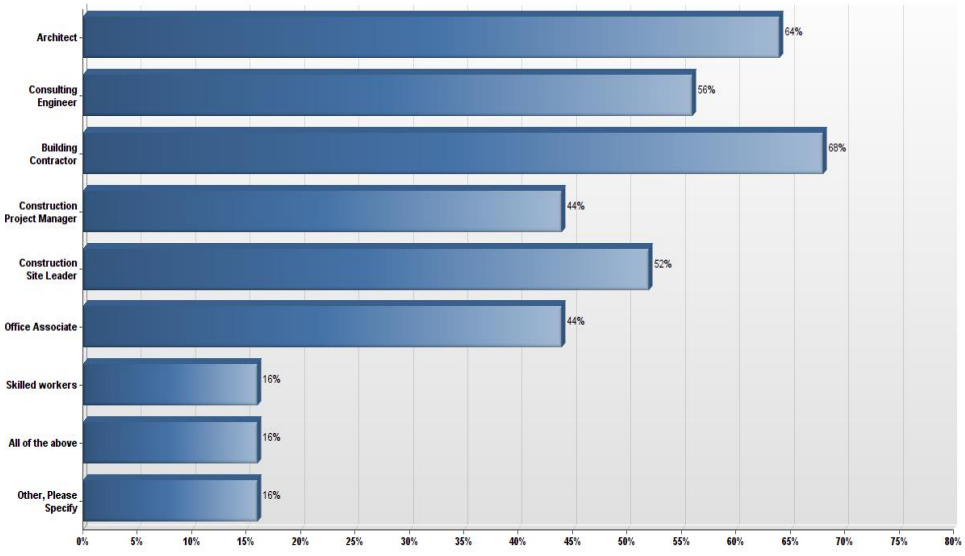

Figure 24. Professionals present at the meeting

Figure 24 indicates that, typically, skilled workers were rarely invited for meetings. Majority of formal meetings were conducted between contractors, architects, engineers, and site-leaders.

20. How do you coordinate and plan the sequence of deliveries with concerned professionals for your daily and weekly operations?

#	Answer	Response	%
1	Coordination is a part of the agreed progress plan	8	33%
2	Weekly Meetings	15	63%
3	Through graphical representation of interconnected tasks	1	4%
4	Don't coordinate deliveries, there is no need	0	0%
5	Other, Please Specify	0	0%
	Total	24	100%

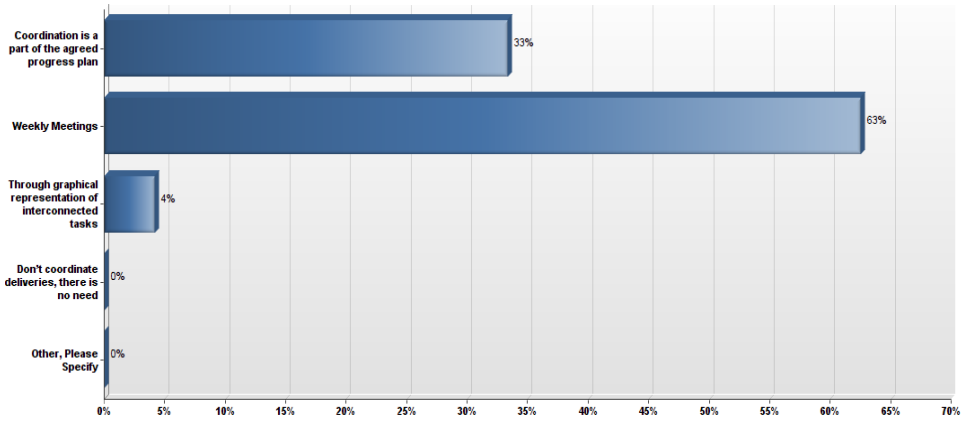

Figure 25. Planning and coordination of construction phases

Figure 25 shows the response to a question intended to understand the process of coordination amongst the project personnel. It can be observed that majority i.e. 63% of the respondents worked in firms where coordination and planning of delivery sequences

was conducted with concerned professionals. Firms representing 33% of the respondents coordinated as part of agreed progress plan. Only one respondent's firm coordinated through the graphical representation of interconnected tasks with concerned professionals within the team.

21. The most important ways to share information with concerned professionals within the project are;

#	Answer	Response	%
1	Intranet (web-portal, common file shares, databases etc)	1	4%
2	E-mails	11	44%
3	Formal meetings	6	24%
4	With the use of 4D, 5D Building Information Modeling Softwares such as Revit, MS Project, Vico Software	1	4%
5	Short Message Service, text messages via mobile phones	0	0%
6	Telephone calls	3	12%
7	Walk around looking (at the construction site to see progress / what needs to be done)	2	8%
8	Talk with the people more randomly (during lunch, breaks etc)	1	4%
	Total	25	100%

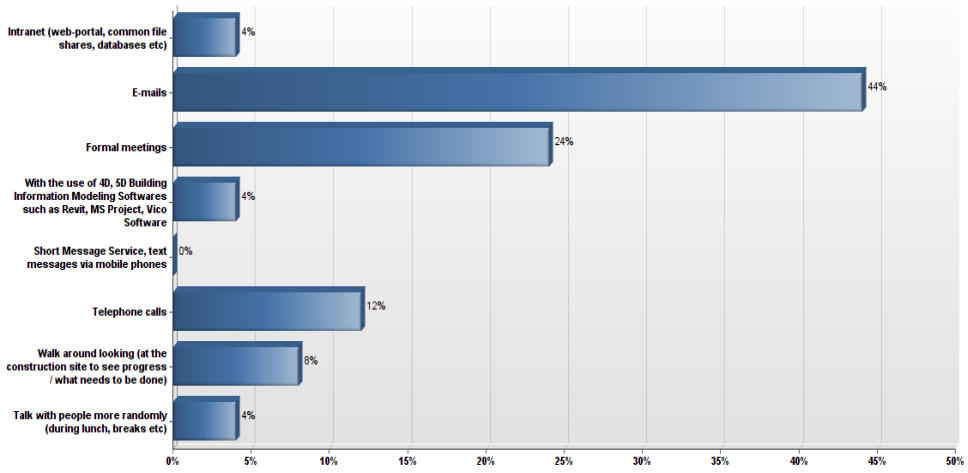

Figure 26. Important ways to communicate within the project with concerned professionals

The data from Figure 26 shows that the primary way for firms to share information with professionals was through emails (44%) followed by formal meetings (24%). The third prominent way of communication was telephone calls (12%). The state-of-the-art tools that can be used for Lean Construction process like BIM or common file sharing system through websites like Dropbox were not established in the Industry in either of the countries (4% each).

22. What do you do in case of lack of materials on site?

#	Answer	Response	%
1	Move people to other construction sites	5	24%
2	Wait, take a break	0	0%
3	Send people home	1	5%
4	Prepare for other work or projects	8	38%
5	Clean the site, Make it tidy during that time	4	19%
6	Other, Please Specify	3	14%
	Total	21	100%

Other, Please Specify
NA
Do a 5 Why on how that could happen
explore other means of acquisition or construction

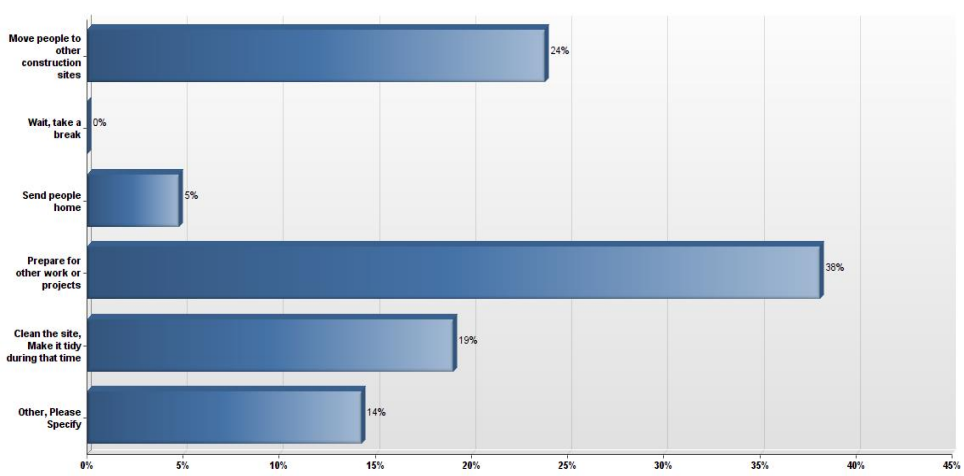

Figure 27. What is done in case of lack of material on construction site?

Figure 27 shows that majority of the respondents (38%) prepared for other projects in case of lack of materials on site. 24% firms moved people to another construction site; in other words resources were moved to other sites. 19% firms cleaned

and tidied up the site during that time while 14% firms explored other ways mentioned in Figure 28. There were 5% firms that sent people home in case of lack of materials on the site.

23. How frequently the firm has faced delays in the project completion?

#	Answer	Response	%
1	0 – 5 times / Year	14	64%
2	5 – 10 times / Year	4	18%
3	10 – 15 times / Year	2	9%
4	15 – 20 times / Year	0	0%
5	More than 20 times / Year	2	9%
	Total	22	100%

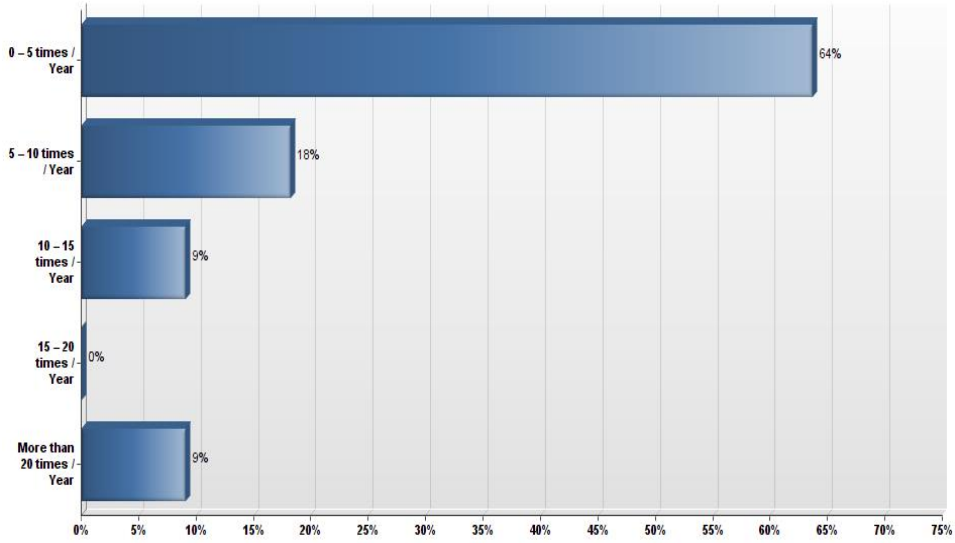

Figure 28. Frequency of project completion delays

Figure 28 indicates that almost 82% of the construction firms within the industry experienced delays up to ten times per year. There were firms experiencing delays 10 to 15 times and more than 20 times per year (each 9% respondents).

24. Are you following the consistent method of managing construction projects over the years?

#	Answer	Response	%
1	Yes	13	62%
2	No	8	38%
	Total	21	100%

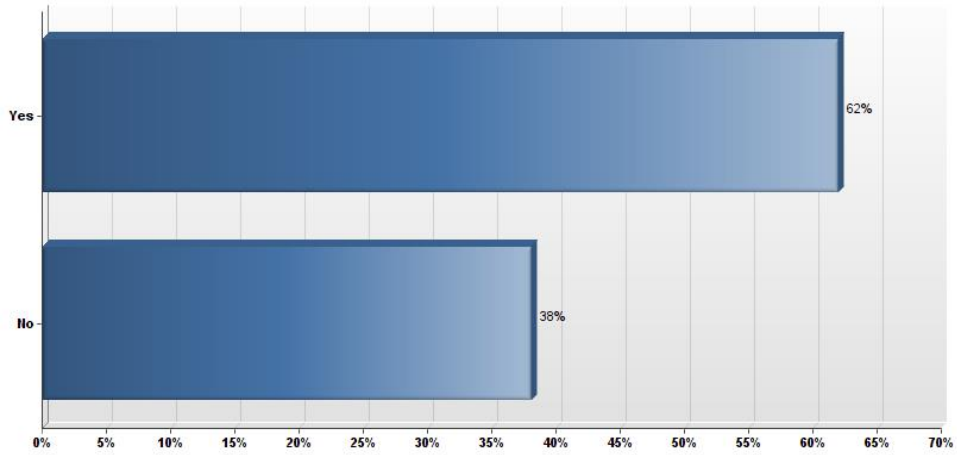

Figure 29. Adaptation of consistent method of construction management over the years.

In conjunction with the previous question, response to question 24 as shown in Figure 29 reveals that 62% of the firms do follow the consistent method of construction management whereas, 38% of the projects in the industry did not follow any established consistent method.

25. Do you keep written record of each outgoing and incoming item on the site which can be presented if asked?

#	Answer	Response	%
1	Yes	16	76%
2	No	5	24%
	Total	21	100%

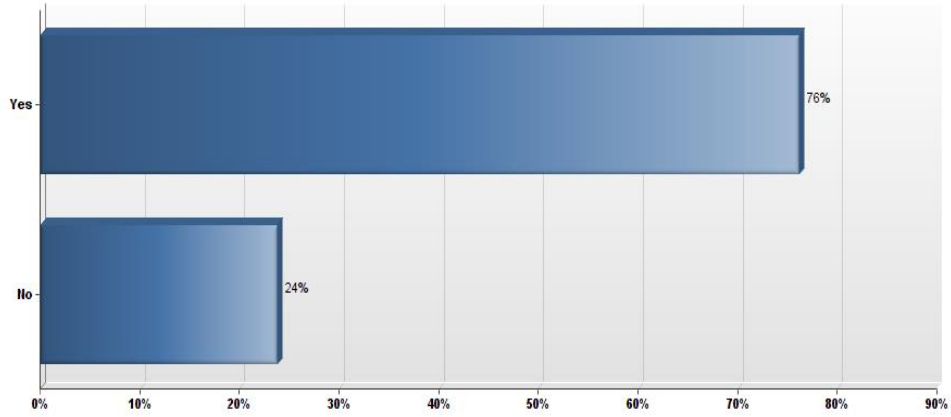

Figure 30. Written record keeping of incoming/outgoing documentation on site.

Figure 30 indicates that communication at construction site was well documented by 76% of the firms while 24% respondents did not keep records of incoming and outgoing documents.

26. Does your company actively participate in the research projects conducted by the academic institutions or other organizations regarding Lean Construction Methods and Techniques?

#	Answer	Response	%
1	Yes	5	23%
2	No	17	77%
	Total	22	100%

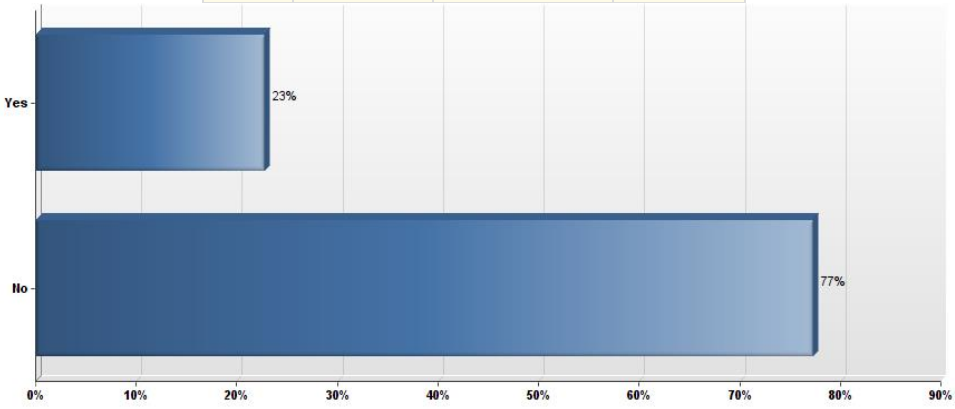

Figure 31. Research project participation of the firm

Figure 31 shows that 77% firms did not update themselves with current market Lean practices by attending conferences or educating themselves through research projects while remaining 23% firms actively participated in research projects.

27. Do member(s) of your company participate in any annual Lean Construction conference?

#	Answer	Response	%
1	Yes, Specify Which	4	20%
2	No	16	80%
	Total	20	100%

Yes, Specify Which
AME Conference
LCI Congress always and several IGLC meetings (Brazil, San Diego)
Lean Construction Institute
LCI, LA

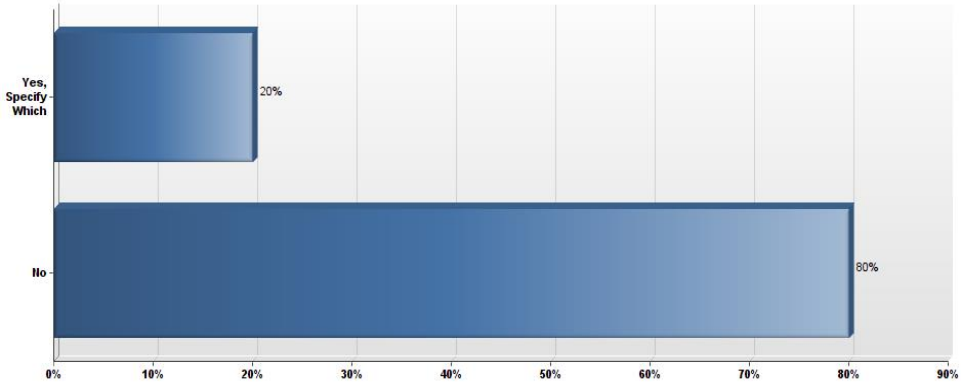

Figure 32. Lean Construction conference participation of the firm

Figure 32 denotes that there was very low participation (20%) from firms in Lean Construction Conferences. Figure 31 and Figure 32 show that, in general, firms did not update themselves with current Lean practices by attending conferences (80%) or educating themselves through research projects (77%).

28. With whom does your company interact more often regarding adoption and application of Lean Construction concepts and methods?

#	Answer	Response	%
1	Clients/Owners	7	50%
2	Academic Institutions	1	7%
3	Other Professionals	6	43%
	Total	14	100%

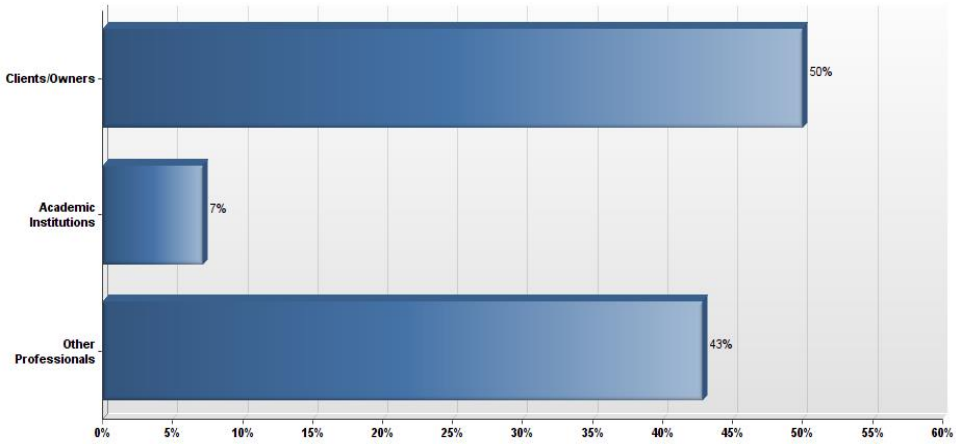

Figure 33. Firm's interaction regarding adoption of Lean Construction methods

Figure 33 shows that 50% of the firms interacted with clients or owners regarding adoption and application of Lean Construction concepts and methods. This followed by 43% of the firms interacting with other professionals with the same purpose. There were only 7% firms that interacted with academic institutions to gain an understanding of Lean methods.

29. During the next year, your company will devote which of the following to the subject of Lean Construction?

#	Answer	Response	%
1	More time and resources	11	52%
2	Less time and resources	4	19%
3	No time and resources	6	29%
	Total	21	100%

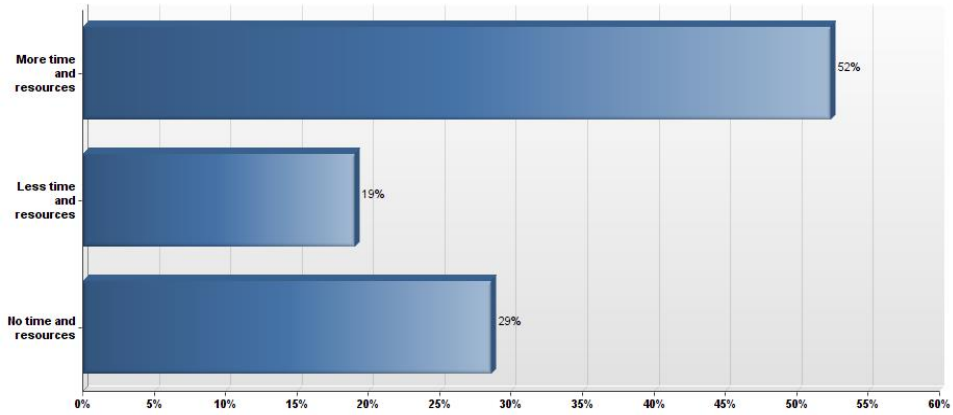

Figure 34. Company's stand regarding investment in the Lean Construction

Question 29 was intended to find out if firms were willing to invest resources to educate themselves with Lean practices. Figure 34 shows that there was willingness in 52% of the construction professionals to invest more time and resources in Lean Construction methods. Remaining 48% professionals would either invest less or no time and resources in Lean Construction methods.

30. Has your company evaluated Lean Construction concepts and methods and reached a decision not to utilize these techniques?

#	Answer	Response	%
1	Yes	5	22%
2	No	18	78%
	Total	23	100%

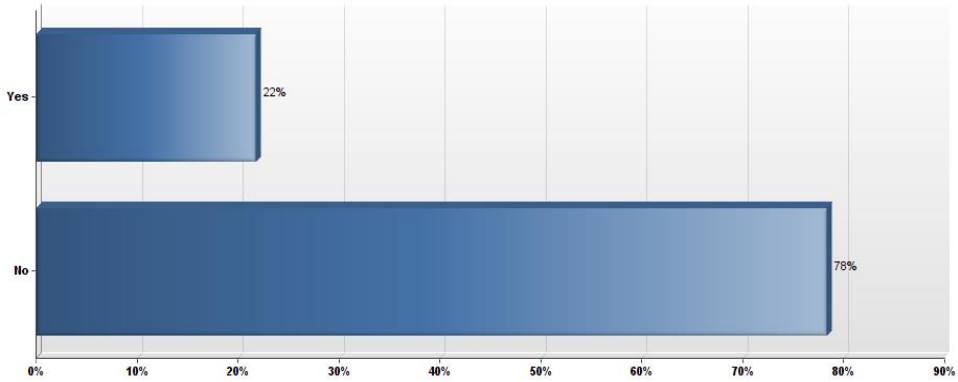

Figure 35. Answer of the respondents to Q.30

Figure 35 indicates that majority of the respondents (78% or 18 individuals) in this study had not reached a decision about using Lean Construction methods after its evaluation by company whereas remaining 22% respondents or 5 individuals had reached a decision not to use Lean Construction methods after its evaluation by company.

31. If your company has decided not to adopt Lean Construction to your practices, what was the critical factor driving this decision?

#	Answer	Response	%
1	Concluded that the concepts & methods do not add value	0	0%
2	Lack of resources to fully evaluate the concepts	5	42%
3	Lack of resources to incorporate, train and deploy	4	33%
4	Other, Please Specify	3	25%
	Total	12	100%

Other, Please Specify
We are a design firm and do not directly engage in construction.
not familiar with

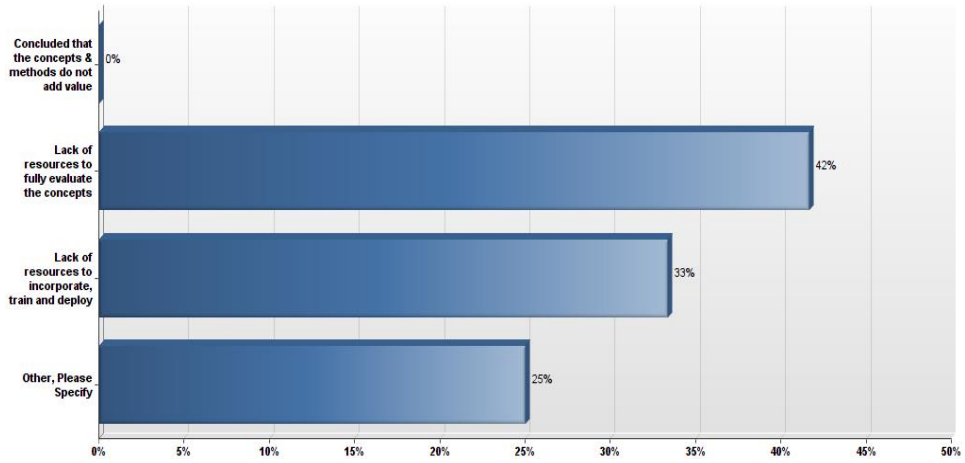

Figure 36. Answer of the respondents to Q.31

In continuation with question 30, Figure 36 shows that one of the main factors driving the decision of not using Lean practices in construction was the lack of resources to fully evaluate the concepts (42%) and lack of training resources for employees to train in this area (33%). 25% firms were either unaware of the concept or did not directly engage in management of onsite construction.

32. Please add any other thoughts or views you have regarding the application and use of Lean Construction methods and concepts in the Indian or American Construction Industry below.
Text Response
Lean is becoming the standard path for continuous improvement in US construction

Figure 37. Answer of the respondents to Q.32

Only one respondent expressed view about Lean Construction method which is listed in Figure 37.

CHAPTER FIVE: CONCLUSION

The purpose of this research was to explore and evaluate differences between construction methods in India and USA by analyzing the methods of minimum wastage and implementation of Lean practices in the construction projects. Lean Construction is adaptation of the Lean manufacturing concepts in the Construction Industry. A questionnaire was prepared and distributed to professionals from both the countries to evaluate current construction practices and awareness about 'Lean Construction concepts'.

The survey was taken by equal number of professionals from India and USA (approximately 50% each) helping to obtain unbiased results. Information was compiled through response to the survey by individuals with very specific knowledge of present construction practices and relevant professional work experience. The level of education and professional experience of the respondents from both countries was the same. Majority of the respondents held the Master's Degree and had a vast experience in the field (more than 20 years). The firms that participated in the survey were of moderate scale in terms of number of employees and annual turnover and had expertise in both residential and commercial projects. The majority of the participating firms were owned privately. This background information gathered via survey implied that the results were indicative of the general trends and practices of the Industry in both the countries and the survey was reliable.

Response to question 11 and question 12 helped to find answers to the first two research questions. Response to question 11 clearly pointed out the difference between the awareness about the term 'Lean Construction' between India and USA. 60% of

respondents from the USA were aware of the term while only 38% of the respondents from India were aware of the term. It can be inferred from this that Indian respondents did not know the term 'Lean Construction' as compared to American respondents. Collectively, 54% of the respondents were not aware of the term. 46% respondents who were aware of the term 'Lean Construction' had continued using Lean methods gaining at least 20% increase in firms' profit. Response to question 12 showed that American Construction Industry is using Lean methods more (75%) compared to Indian Construction Industry (57%). Several authors have studied the methods of minimizing wastage in Construction Industry. Dr. Siddique, R. (n.d.) discussed the state of the Cement Industry, utilization of Fly Ash, and Construction Waste in construction related activities in India. Bhattacharjee, B. (2010) concluded that there was a need for being concerned about sustainability of concrete in India and minimizing the wastage of precious natural resources by making their efficient and judicious use. These studies suggested some alternatives to the concrete use in Indian Construction Industry. Sustainability could be achieved through extensive use of Ready Mix Concrete (RMC) practices, use of High Volume Fly Ash (HVFA) which is the byproduct produced during the combustion of coal, Self-Compacting Concrete (SCC) in construction related activities and prefabrication wherever possible. American Construction Industry has already taken steps toward construction automation. Additionally, Building Information Modeling (BIM) is another useful tool to minimize wastage.

Results gathered from the set of questions related to current managerial practices showed that there were few Lean principles used by firms within either of the countries. There was no consistency with the use of Lean principles in each step of the supply chain

of the construction process resulting in the delay of projects every year. In both the countries, firms kept record of incoming and outgoing items to and from the construction sites. Also, firms worked on other projects or moved resources to other sites in case of the lack of materials and held weekly meetings to discuss progress. This added value to the business practices in both the countries. However, only higher authorized professionals attended such meetings. There was similarity in business practices across the two countries as far as frequency of communication, mode of communication and involvement of personnel in decision making was concerned. There was a lack of systematic measures to optimize unused material in the firms from USA (67%). This practice was even more evident in Indian firms (85%). It was apparent that there was a general awareness about resource utilization, although there was a lack of processes in place indicating proper methods such as Lean. Also, the disadvantages due to inadequate use of Lean methods had not been fully and correctly quantified since the importance of such practice had not yet been realized. Most firms were following the same construction methods over the years and were not willing to change or update the practices. It was observed that the Construction Industry in the USA was far ahead of the Indian Construction Industry as far as active participation in research and developmental activities and knowledge exchange within the Industry was concerned. Also, firms within the USA attempted to engage clients with Lean practices while there was no clear evidence of such an initiative within Indian firms. Lack of time and resources to train was a typical reason for insufficient exposure to updated knowledge of Lean methods. One important and interesting observation was the response to question 30. It indicated that in spite of evaluating advantages of Lean methods, there was a portion of industry in both

countries that decided not to implement the necessary Lean tools (22% in USA and 25% in India).

Lastly, the research indicated that there was an increasing response to the use of Lean Construction methods in developed country like USA as well as in a developing country like India. This suggested a need for education, training and an increased awareness about the Lean Construction methods and concepts in Indian as well as in the American Construction Industry.

Recommendations for Future Studies

Additional research on the topic of Lean Construction would be beneficial to the Indian and American Construction Industry. First recommendation for further research is to conduct similar research on ongoing live projects of similar scale in India and USA simultaneously. It will also be interesting to see the results after Lean and Six Sigma principles are implemented together in a project.

The second recommendation for future research is to design the survey in a manner that it is easy and clear to compare Lean Construction practices in India and USA. The increased sample size will also be beneficial.

The third recommendation is to conduct a similar study in a more specific area of the Construction Industry such as focusing Lean method usage only in architectural projects from India and from USA.

The fourth recommendation for future research is to survey the academic community from both the countries. Knowledge of the new topics often comes from Universities, Schools, and other academic organizations. Research showing whether the

academic community is aware of Lean Construction principles and if the Lean methods are being taught or not could be beneficial.

The final recommendation for future study is to see whether there is a correlation between level of education of respondent and awareness about Lean methods in the firm. Such research will reveal if employees with higher education are responsible for introducing Lean Construction to firms.

APPENDIX A: Implied Consent for Survey

Implied Consent for Survey

Title of Project: "Comparison of lean construction in India & USA"

Principal Investigator: Vedangi Mahashabde
Architectural & Manufacturing Sciences Department
Western Kentucky University
vedangi.mahashabde361@topper.wku.edu

Faculty Advisor: Dr. Daniel Jackson (Committee Chair)
Architectural & Manufacturing Sciences Department
Western Kentucky University
dan.jackson@wku.edu

You are being asked to participate in a project conducted through Western Kentucky University. The University requires that you give your agreement to participate in this project. ***You must be 18 years of age or older to take part in this research study.***

The investigator will explain to you in detail the purpose of the project, the procedures to be used, and the potential benefits and possible risks of participation. You may ask him/her any questions you have to help you understand the project. A basic explanation of the project is written below. Please read this explanation and discuss with the researcher any questions you may have. You should be given a copy of this form to keep.

As a graduate student in the Architectural & Manufacturing Sciences Department and under the supervision of Dr. Jackson, Associate Professor in the Architectural & Manufacturing Sciences Department at Western Kentucky University, I am conducting research for my thesis **titled as "**Comparison of lean construction in India & USA**"**

Purpose of the Study: The purpose of this research study is to contribute in the field of construction in the United States and India both by analyzing the methods of minimum wastage and lean thinking implemented in architectural projects in both of these countries.

Procedures to be followed: You will be asked to answer questions on a survey via link. Carefully read the instructions, question statements and choices. Try to be objective and true as much as you can. Unless stated otherwise, pick one choice for each question. Try to answer all questions.

Discomforts and Risks: There are NO foreseeable risks associated with this research project and the probability and magnitude of harm or discomfort anticipated in the research is no more than in daily life.

Benefits: While you may not benefit directly from participation in this study, it is hoped that the knowledge gained through your participation will help society at a later time.

Duration: It will take about twenty to thirty minutes to complete the survey.

Statement of Confidentiality: Your participation in this research is confidential and anonymous. And your confidentiality will be kept to the degree permitted by the technology used. The survey does not ask for any information that would identify who the responses belong to. The information will be used solely for academic purposes.

Voluntary Participation: Refusal to participate in this study will have no effect on any future services you may be entitled to from the University. Anyone who agrees to participate in this study is free to withdraw from the study at any time with no penalty.

You understand also that it is not possible to identify all potential risks in an experimental procedure, and you believe that reasonable safeguards have been taken to minimize both the known and potential but unknown risks.

Your continued cooperation with the following survey implies your consent.

https://wku.qualtrics.com/SE/?SID=SV_2sp66iCHXUY8LvT (The Survey Link)

THIS PROJECT HAS BEEN REVIEWED AND APPROVED BY
THE WESTERN KENTUCKY UNIVERSITY INSTITUTIONAL REVIEW BOARD
Paul Mooney, Human Protections Administrator
TELEPHONE: (270) 745-2129

APPENDIX B: IRB Approval Letter

INSTITUTIONAL REVIEW BOARD
OFFICE OF RESEARCH INTEGRITY

DATE:	March 11, 2014
TO:	Vedangi Mahashabde
FROM:	Western Kentucky University (WKU) IRB
PROJECT TITLE:	[569705-1] COMPARISION OF LEAN CONSTRUCTION IN INDIA AND UNITED STATES OF AMERICA
REFERENCE #:	IRB 14-330
SUBMISSION TYPE:	New Project
ACTION:	APPROVED
APPROVAL DATE:	March 11, 2014
REVIEW TYPE:	Exempt from Full Board Review

Thank you for your submission of New Project materials for this project. The Western Kentucky University (WKU) IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Exempt from Full Board Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding followed by an *implied* consent form. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this office.

This project has been determined to be a Minimal Risk project.

Please note that all research records must be retained for a minimum of three years after the completion of the project.

If you have any questions, please contact Paul Mooney at (270) 745-2129 or irb@wku.edu. Please include your project title and reference number in all correspondence with this committee.

APPENDIX C: CITI Course Report

COLLABORATIVE INSTITUTIONAL TRAINING INITIATIVE (CITI)

BASIC/REFRESHER COURSE - HUMAN SUBJECTS RESEARCH CURRICULUM COMPLETION REPORT

Printed on 02/10/2014

LEARNER	Vedangi Malhashabde (ID: 4005864) 211 Village Green Dr Apt D7 Hopkinsville Kentucky 42240 United States
DEPARTMENT	Architectural & Manufacturing Sciences
PHONE	9312523605
EMAIL	vedangi.mahashabde361@topper.wku.edu
INSTITUTION	Western Kentucky University
EXPIRATION DATE	02/09/2017

SOCIAL/BEHAVIORAL RESEARCH COURSE

COURSE/STAGE:	Refresher Course/2
PASSED ON:	02/10/2014
REFERENCE ID:	12331458

REQUIRED MODULES	DATE COMPLETED	SCORE
SBE Refresher 1 – Defining Research with Human Subjects	02/10/14	2/2 (100%)
SBE Refresher 1 – Privacy and Confidentiality	02/10/14	2/2 (100%)
SBE Refresher 1 – Assessing Risk	02/10/14	2/2 (100%)
SBE Refresher 1 – Research with Children	02/10/14	2/2 (100%)
SBE Refresher 1 – International Research	02/10/14	2/2 (100%)
SBE Refresher 1 – History and Ethical Principles	02/10/14	2/2 (100%)
SBE Refresher 1 – Federal Regulations for Protecting Research Subjects	02/10/14	2/2 (100%)
SBE Refresher 1 – Informed Consent	02/10/14	2/2 (100%)
SBE Refresher 1 – Research with Prisoners	02/10/14	2/2 (100%)
SBE Refresher 1 – Research in Educational Settings	02/10/14	1/2 (50%)
Western Kentucky University	02/09/14	No Quiz

For this Completion Report to be valid, the learner listed above must be affiliated with a CITI Program participating institution or be a paid independent Learner. Falsified information and unauthorized use of the CITI Progam course site is unethical, and may be considered research misconduct by your institution.

Paul Braunschweiger Ph.D.
Professor, University of Miami
Director Office of Research Education
CITI Program Course Coordinator

APPENDIX D: The Questionnaire

Q1. Your Education;

- Associate's Degree in _____
- Bachelor's Degree in _____
- Master's Degree in _____
- Doctorate in _____
- Other, Please Specify _____

Q2. Your Profession/ Role in the Company;

- Architect
- Consulting Engineer
- Building Contractor
- Construction Project Manager
- Construction Site Leader
- Office Associate
- Other, Please Specify _____

Q3. Your Level of Experience (In Years);

- 0 – 5
- 5 – 10
- 10 – 15
- 15 – 20
- More than 20

Q4. Company's Complete Name

_____

Q5. Geographical Operational Locations of the Firm;

- All within India
- All Within USA
- Spread within the Country and Abroad

Q6. Areas of Expertise of the firm (More than one choice can be picked!);

- Primarily Residential Projects (Bungalows/ Individual Houses, Apartments, etc.)
- Primarily Commercial Projects (Theaters, Institutions, Religious Buildings)
- Both Residential & Commercial Projects
- Industrial Facilities
- Energy Efficient/ Green Buildings
- Infrastructural Facilities (Airports, Highways, Dams, Bridges, Tunnel Construction)

Q7. The firm is active in Construction Industry since (In Years);

- 0 – 5
- 5 – 10
- 10 – 15
- 15 – 20
- More than 20

Q8. Average number of employees in the firm (Including Construction Sites and Offices);

- 10 – 100
- 100 – 500
- 500 – 1500
- More than 1500

Q9. Average annual turnover of the firm; (In Million American Dollars)

- $ 1 – 10
- $ 10 – 100
- $ 100 – 1000
- More than $ 1000

Q10. Major Clients of the firm;

- Public / Government Organizations (State/ Federal)
- Private Individuals and Organizations
- Both Public and Private Organizations

Q11. Are you familiar with the term 'Lean Construction' as an approach in managing the construction process?

- Yes
- No

If 'No' is selected, then skip to Q.17

Q12. Do you currently utilize Lean Construction methods or concepts in your construction projects?

- Yes
- No

Q13. For how many years has the company been utilizing Lean Construction concepts and methods in the projects?

Q14. The following choices represent opinions expressed in recent editorials and publications. Which of these definitions of Lean Construction is closest to your own?

- The holistic pursuit to the elimination of material 'Waste' on a construction project
- Kaizen (Japanese word for continuous and step-wise quality improvement)
- The continuous process of eliminating 'Waste', meeting or exceeding all customer requirements, focusing on the entire value stream, and pursuing perfection in the execution of the constructed project.
- Other _____

Q15. Has your company identified tangible benefits from utilizing Lean Construction practices that have enhanced your company profits?

- Yes (Example) _____
- No

Q16. What is the profit percentage of your firm due to usage of Lean Construction practices?

- 0 – 20 %
- 20 – 40 %
- 40 – 60 %
- 60 – 80 %
- 80 – 100 %

Q17. Is there a system at the firm that measures and evaluates the quantity of unused and/or unnecessarily purchased materials and tools?

- Yes
- No

Q18. How often do you meet to discuss responsibilities and plans with the professionals involved?

- Each day
- Each week
- Every second week
- As problems arises (when necessary)
- Other _____

Q19. Who is present at the meetings? (More than one choice can be picked!)

- Architect
- Consulting Engineer
- Building Contractor
- Construction Project Manager
- Construction Site Leader
- Office Associate
- Skilled workers
- All of the above
- Other, Please Specify _____

Q20. How do you coordinate and plan the sequence of deliveries with concerned professionals for your daily and weekly operations?

- Coordination is a part of the agreed progress plan
- Weekly Meetings
- Through graphical representation of interconnected tasks
- Don't coordinate deliveries, there is no need
- Other, Please Specify _____

Q21. The most important ways to share information with concerned professionals within the project are;

- Intranet (web-portal, common file shares, databases etc)
- E-mails
- Formal meetings
- With the use of 4D, 5D Building Information Modeling Softwares such as Revit, MS Project, Vico Software
- Short Message Service, text messages via mobile phones
- Telephone calls
- Walk around looking (at the construction site to see progress / what needs to be done)
- Talk with people more randomly (during lunch, breaks etc)

Q22. What do you do in case of lack of materials on site?

- Move people to other construction sites
- Wait, take a break
- Send people home
- Prepare for other work or projects
- Clean the site, Make it tidy during that time
- Other, Please Specify _____

Q23. How frequently the firm has faced delays in the project completion?

- 0 – 5 times / Year
- 5 – 10 times / Year
- 10 – 15 times / Year
- 15 – 20 times / Year
- More than 20 times / Year

Q24. Are you following the consistent method of managing construction projects over the years?

- Yes
- No

Q25. Do you keep written record of each outgoing and incoming item on the site which can be presented if asked?

- Yes
- No

Q26. Does your company actively participate in research projects conducted by academic institutions or other organizations regarding Lean Construction methods and techniques?

- Yes
- No

Q27. Do member(s) of your company participate in any annual Lean Construction conference?

- Yes, Specify Which _____
- No

Q28. With whom does your company interact more often regarding adoption and application of Lean Construction concepts and methods?

- Clients/Owners
- Academic Institutions
- Other Professionals
- None of the above

Q29. During the next year, your company will devote which of the following to the subject of Lean Construction?

- More time and resources
- Less time and resources
- No time and resources

Q30. Has your company evaluated Lean Construction concepts and methods and reached a decision not to utilize these techniques?

- Yes
- No

Q31. If your company has decided not to adopt Lean Construction to your practices, what was the critical factor driving this decision?

- Concluded that the concepts & methods do not add value
- Lack of resources to fully evaluate the concepts
- Lack of resources to incorporate, train and deploy
- Other, Please Specify _____

Q32. Please add any other thoughts or views you have regarding the application and use of Lean Construction methods and concepts in the Indian or American Construction Industry below.

_____

_____

_____

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